DOCUMENT RESUME

ED 191 660 SE 031 626

AUTHOR Ricker, Kenneth S.
TITLE Teaching Biology to Visually Handicapped Students. Resource Manual.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE Jun 80
GRANT SPI-7803745-A01
NOTE 158p.: Photographs will not reproduce well.

EDRS PRICE MF01/PC07 Plus Postage.
DESCRIPTORS *Biology: Higher Education: *Laboratory Procedures: *Low Vision Aids: Science Activities: Science Education: Science Instruction: *Science Materials: Secondary Education: *Visual Impairments

ABSTRACT

This resource manual presents numerous techniques for adapting science activities to the visually handicapped student, applicable to introductory biology courses in which microscopes are used extensively in the laboratory. Chapters include information on the following: alternative microscopic viewing techniques, physical models, tactile diagrams, measuring techniques, alternative activities and materials (genetics, bacteria, mapping chromosomes, mitotic indexing, blood typing, osmosis), and other techniques (mathematical problems, lab reports, tactile record sheets, safety considerations, sensors, Sewell embossing, and snail dot inverter). An appendix lists sources of materials and equipment for the visually handicapped. (CS)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED191660

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Kenneth S. Ricker
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

RESOURCE MANUAL

TEACHING BIOLOGY TO VISUALLY HANDICAPPED STUDENTS

Kenneth S. Ricker
Department of Science Education
University of Georgia
Athens, Georgia 30602

June, 1980

This material is based upon work supported by the National Science Foundation under Grant No. SPI-7803745 A01. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the National Science Foundation.

SE 031 626

PREFACE

Only within the last few years have there been any systematic efforts to examine the teaching of college science to visually handicapped students. These recent efforts have been stimulated greatly by the Physically Handicapped in Science Program of the National Science Foundation. In 1977 the Foundation began funding projects to generate knowledge about the problems physically handicapped persons encounter in trying to become scientists and ways to overcome these problems; and to develop science training models that involve handicapped students at the secondary and college levels.

The absence of prior efforts to teach science to visually handicapped college students is related in part to the lack of opportunities for many visually handicapped persons to attend undergraduate schools. In addition, many visually handicapped persons who have attended undergraduate schools have been excluded from college science laboratory courses. Recent federal legislation (e.g., Section 504 of the Rehabilitation Act of 1973) means that there will be more opportunities for visually handicapped persons to attend colleges and universities. Once the All Handicapped Children Law (PL 94-142) is fully implemented there will be more visually handicapped secondary students prepared to seek admission to undergraduate school.

This resource manual is based on the activities of a National Science Foundation Project, College Biology and the Visually Handicapped. In essence the project examined an introductory biology laboratory course in order to determine ways by which it could be made accessible to visually handicapped students. The manual was written to help other biology instructors in similar situations. For the most part the contents of the manual are related to techniques that are applicable to introductory biology courses in which microscopes are used extensively in the laboratory.

The manual has eight chapters: an introductory chapter to give an overview of the project; six chapters to describe different techniques that the project examined in its effort to design modifications and alternative activities for the regular laboratory activities that could not be done by students due to a visual impairment; and a brief concluding chapter.

It would have been impossible to generate the knowledge contained in this manual without the assistance of the student consultants. I extend my gratitude to Sharon Belden, Rufus Bosley, Kathleen Cheever, Theodore Goodwin, Evelyn Griffin, Michael Hall, James Holsomback, Michael Lewis, Ben Manley, Jr., Clifford R. Roberts, and Gaylon Tootle. I also wish to express my appreciation to the project staff--Leon Benefield, Carolyn Bradley, Nancy Rodgers and Susan Smith Elfström--and to the project advisors. The project could not have been completed without the support of the faculty and staff of the Department of Science Education of the University of Georgia.

Kenneth S. Ricker

TABLE OF CONTENTS

	Page
LIST OF FIGURES	v
Chapter	
1. Introduction	1
2. Alternative Microscopic Viewing Techniques	5
3. Physical Models	12
4. Tactile Diagrams	21
5. Measuring Techniques	41
6. Alternative Activities and Materials	57
7. Other Techniques	76
Mathematical Problems	76
Lab Reports	76
Tactile Record Sheets	77
Safety Considerations	79
Sensors	80
Tactile Diagrams -- Not Reproducible	81
8. Conclusion	92
APPENDIX A, Sources	93

LIST OF FIGURES

Figure		Page
2-1.	Microprojector	7
2-2.	Micro-Slide-Viewer	7
2-3.	Television System	9
2-4.	Viewing Screen	9
2-5.	Rear Viewing Screen	10
2-6.	Rear Screen Projector	10
3-1.	Animal Cell	15
3-2.	Mitosis	17
3-3.	Pop-It Beads	17
3-4.	Types of Bacteria	19
3-5.	Groups of Bacteria	19
4-1.	Ink Drawing: Onion Skin Cell	23
4-2.	Ink Drawing: Anaphase	24
4-3.	*Elodea* Cell: Master Diagram	27
4-4.	Anaphase I: Master Diagram	28
4-5.	*Euglena* Cell: Master Diagram	29
4-6.	Blood Smear: Master Diagram	30
4-7.	*Elodea* Cell: Copy	31

Figure		Page
4-8.	Anaphase I: Copy	32
4-9.	Euglena Cell: Copy	33
4-10.	Blood Smear: Copy	34
5-1.	Modified Syringes	42
5-2.	Mounted Syringes	44
5-3.	Squeeze Type Dispensers (Fixed Volume)	46
5-4.	Squeeze Type Dispenser (Variable Volume)	48
5-5.	Pipet Filling Device (Fixed Volume)	48
5-6.	Pipet Filling Device (Variable Volume)	48
5-7.	REPIPET Jr. (Fixed Volume)	50
5-8.	REPIPET Jr. (Variable Volume)	50
5-9.	Liquid Level Sensor	51
5-10.	Modified Balance	53
5-11.	Thermometer	55
5-12.	Ruler	55
6-1.	Magnetic Punnett Square	59
6-2.	Genetics Made Easy, 1	61
6-3.	Genetics Made Easy, 2	64
6-4.	Bacteria Plate 1	66
6-5.	Bacteria Plate 2	67

Figure		Page
6-6.	Mapping Chromosomes	70
6-7.	Crossing Over	71
6-8.	Mitotic Index	72
6-9.	Blood Typing	73
7-1.	Genetics Record Sheet	78
7-2.	Sensors	82
7-3.	Audicator	83
7-4.	Sewell Board	86
7-5.	Swail Dot Invertor	87
7-6.	*Euglena* Cell	89
7-7.	Onion Skin Cell	90

CHAPTER 1 -- Introduction

The contents of this resource manual are based on the project "College Biology and the Visually Handicapped." The primary purpose of the project was to enhance the opportunities for success for visually handicapped students enrolled in introductory college laboratory biology. The project examined the instructional strategies used in a laboratory biology course to identify those instructional strategies which required modification or replacement with alternative strategies; to suggest appropriate modifications and alternative strategies when a need was identified; and to develop and pilot test prototype materials and procedures.

The instructional strategies regularly used in the laboratory were examined in terms of the needs of three types of visually handicapped persons: those people who function primarily using a visual mode, a tactile mode, or a combination of these modes. Visually handicapped students from these three categories worked with the project staff to analyze the regular instructional strategies. They suggested modifications and alternatives; and participated in pilot testing the use of prototype materials and procedures.

The manual describes the results of the project's efforts. The reader should keep in mind that the project's focus was on Biology 101, an introduction laboratory biology course at the University of Georgia. The project activities were limited in scope to the laboratory activities found in this course. For example, the students use microscopes extensively in the laboratory portion of the course.

Twelve visually handicapped college students served as project consultants. These students were not currently enrolled in Biology 101. Most of them had already completed the science requirement. The strategies designed by the project were tested by using simulated lab sessions. Two persons who served

as project advisors were also visually handicapped. While these fourteen persons reflect many common characteristics of the visually handicapped, they are all individuals with their own unique ways of functioning. The project demonstrated something well known, but not commonly observed: the people who compose the group labeled visually handicapped (or legally blind, or partially sighted, etc.) represent a population just as heterogeneous as the total population of non-handicapped persons. Although the manual does not attempt to resolve problems related to teaching biology to visually handicapped students nationwide, a number of techniques are generalizable to biology instruction in general and have implications for instructors who have visually handicapped students enrolled in their courses.

As a means of illustrating the heterogenity of this group of students classified as visually handicapped, data on six of them are given below.

Student 1. Totally blind from birth; no visual

memory; excellent tactile reader of braille and with the Optacon.

Student 2. Totally blind from age of twelve; excellent visual memory; fair tactile reader of braille.

Student 3. Totally blind from about age twenty as a result of a war injury; excellent visual memory; poor tactile reader of braille.

Student 4. Totally blind after the age of forty as a result of a disease; excellent visual memory; unable to become a proficient reader of braille for neurological reasons.

Student 5. Partially sighted from birth; excellent tactile reader of braille and fair reader of large print.

Student 6. Partially sighted for only three years; excellent reader of large print; sensitive to light.

In terms of the project goals, the twelve students had only one thing in common--not one student could use a regular microscope to perform laboratory activities.

The manual describes techniques that were effective, as well as those that were ineffective for the project. A technique which may be successful in one laboratory setting may not be successful in another; and vice versa. Promising potential modifications and alternatives that the project was not able to assess because of time and material restrictions are also given.

The project attempted to design a variety of techniques that would make the regular biology course accessible to students with all types of visual impairments. Techniques that would enable the visually handicapped students to be active learners were sought so the students could mentally and physically participate in the laboratory activities, and not be placed in a subservient role by having to rely on a sighted lab partner. The project recognized

that it generally takes visually handicapped students more time to complete lab activities than sighted students. This factor was taken into consideration when alternative activities were designed.

The project identified a number of variables that appeared to influence learning of the visually handicapped students and used these in designing modifications and alternative activities. Some examples of the variables that can influence the learning styles of visually impaired students are:

1. Do they have any residual vision and if so, how effectively can they use it?
2. Do they have any visual memory?
3. Do they rely on tactile information and if so, how effective are they in gathering and interpreting tactile data?
4. To what extent have they acquired the skills that will enable them to function independently in the college environment?
5. At what cognitive level is the student functioning?

The project sought ways to provide equal opportunities for the visually handicapped students to succeed in a biology course. These opportunities

stress approaches to instruction which maximize the best functioning input modalities and minimize those modalities with limited input capabilities.

An instructor who has a visually handicapped student in class should meet with the student to review these variables and to determine the student's best developed and most successful input modality for learning. Media considerations generally include: braille and other tactile media, large print, taped and audio materials, and perhaps reader or tutorial services. Some visually handicapped students will be able to make suggestions as a result of their previous experiences. Other visually handicapped students will be able to make only a few, if any, specific suggestions since it will be the first time that they ever had to face the problems involved in a laboratory biology course.

CHAPTER 2 -- Alternative Microscopic Viewing Techniques

Students enrolled in biology are expected to use a microscope in many of the laboratory exercises. The project sought alternative microscopic viewing techniques to afford visually handicapped students who are not able to use the laboratory microscope access to the same information gained by the students who can use a microscope. The alternative techniques that were investigated for use with the visually handicapped students with useful residual vision are described in this chapter. Techniques which were not actually tested by the project, but appear to be viable techniques, are also identified.

The instructor who has a visually handicapped student in class should assess the situation in terms of the instructional materials and equipment available for use and the specific needs of the visually handicapped student. The descriptions of the following techniques may assist the instructor in the assessment.

Microprojector

The most common kind of microprojector can be used to project images on a wall screen for large group viewing or on a table top for small group viewing. A wide range of magnification factors are available for use with the instrument. A small compact microprojector with a built-in screen is also available for small group viewing. The degree of magnification obtained with the compact microprojector is limited. The project examined only the use of the first type of microprojector (Figure 2-1).

When the image is projected on a white mat on the table top or on a wall screen the visually handicapped students can view the enlarged image. The students can vary their viewing distance by simply moving their heads closer or farther away from the image. A student may also use a magnifying lens to study specific portions of the image in greater detail. Either commercial microscopic slides or slides

prepared in the laboratory can be used. The fact that either dry or wet slides can be used with the micro-projector is an advantage. It is not possible to use microscopic slides with most of the other techniques that are described below.

Micro-Slide-Viewer

The Micro-Slide-Viewer is a commercial device that permits the user to examine photomicrographs of biological specimens (Figure 2-2). This instrument should be considered as a possible technique particularly for those students who are sensitive to light. Only a small amount of indirect lighting is needed to use the device. One student working with the project was able to examine specimens with this device while unable to use any of the other optical techniques that were tried. Since regular microscopic slides are not used with the device, the use of the Micro-Slide-Viewer is limited by the number of microslides that are available. Presently there are about fifty sets of microslides available that are

biological in nature. In those laboratories where photomicrographing is used the instructor does not necessarily have to be limited by the nature and number of microslides that are commercially available. It is possible to view two by two slide transparencies with the viewer. It is only necessary to cut a narrow strip off the mount of the two by two slide so it can be inserted into the viewer.

Closed Circuit Television Systems

There are two general types of closed circuit television systems which can be used with visually handicapped students. The most common type is the system that is especially designed for use by visually handicapped persons. The person examines the enlarged image of what the camera views on a monitoring screen.

The second system is specifically designed for use with microscopes. Special attachments are available so television cameras can be attached to a microscope and the resulting image projected on to a television screen. A recent article describes a way



Figure 2-1. Microprojector.



Figure 2-2. Micro-Slide-Viewer.

to use a video camera with a microscope without the need for any special devices or attachments. [Pulley, James B. "Video Microprojection in Your Classroom." The Science Teacher, 46:33 (December, 1979).]

The project studied the use of the first type of closed circuit television system (Figure 2-3). The students view enlarged pictures and diagrams of specimens on the monitoring screen. The use of this system permits the instructor to use the diagrams and pictures in the textbook and laboratory manual, or from any other source. The degree of magnification, contrast, and type of image (positive or negative) is varied by the user of the system. The negative image was particularly useful for one student who is sensitive to light. The use of this system is limited to diagrams and pictures of specimens whereas the other television employs a laboratory microscope and uses regular microscopic slides.

Microscope Viewing Screens

Several kinds of viewing screens that fit directly on the microscope are available. These screens project an image upwards of eight times the image viewed through the microscope. The project tried one of these viewing screens (Figure 2-4) but was unable to obtain images with sufficient clarity for use with visually handicapped students.

Rear Viewing Screen

Two different rear viewing arrangements were examined. In one arrangement a small inexpensive screen that permits rear viewing was used with a 35 mm projector (Figure 2-5). The projector is set about three feet away from the screen so as to project the complete image on the screen. The student views the image on the side of the screen away from the projector. The student varies his/her viewing distance by moving closer or farther away from the screen. A student may also be able to use a

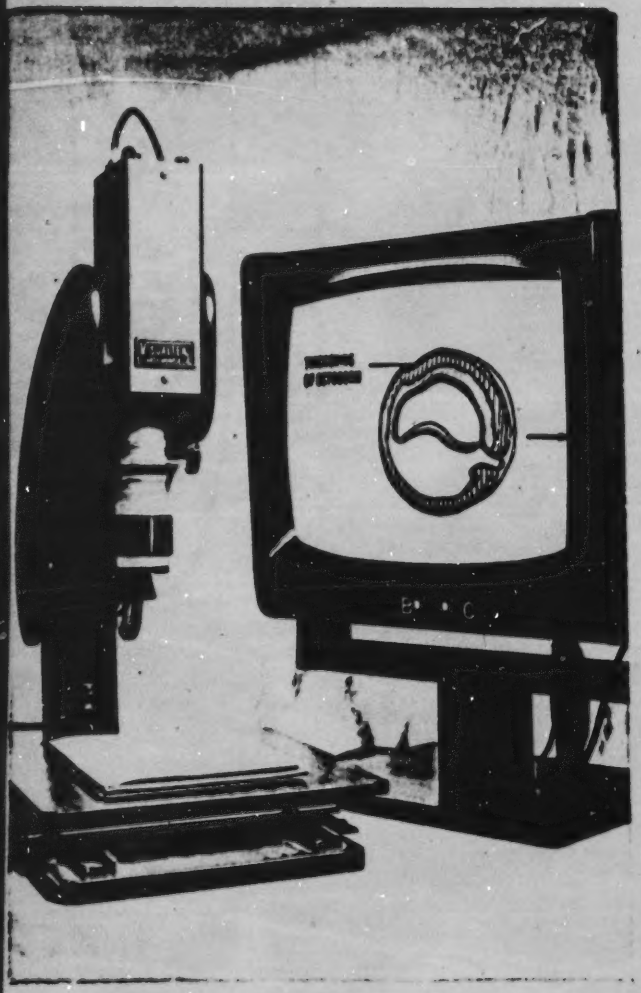


Figure 2-3. Television System.

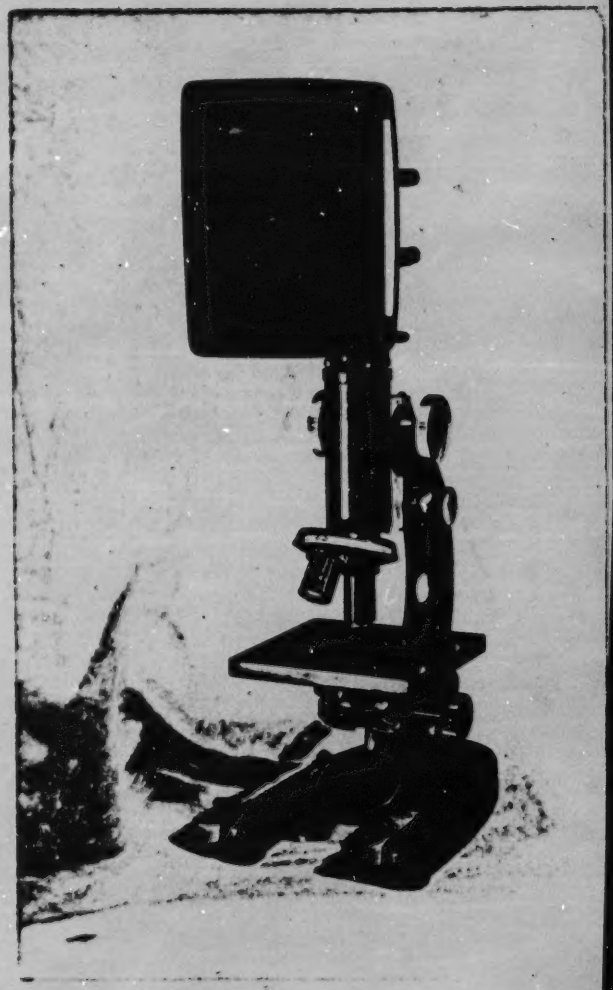


Figure 2-4. Viewing Screen.

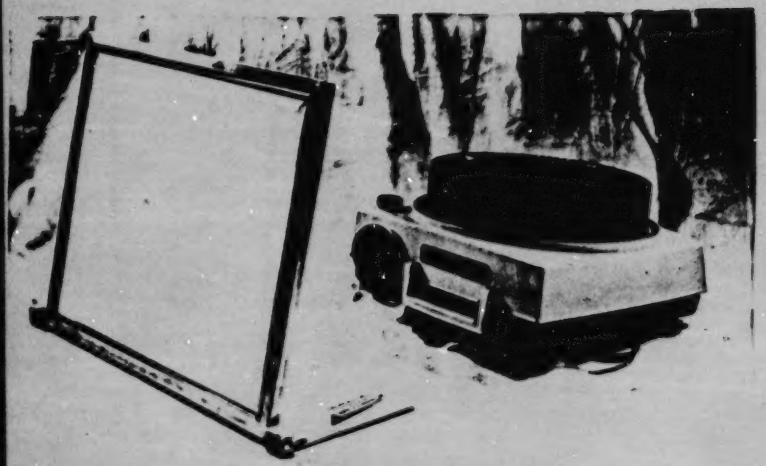


Figure 2-5. Rear Viewing Screen.

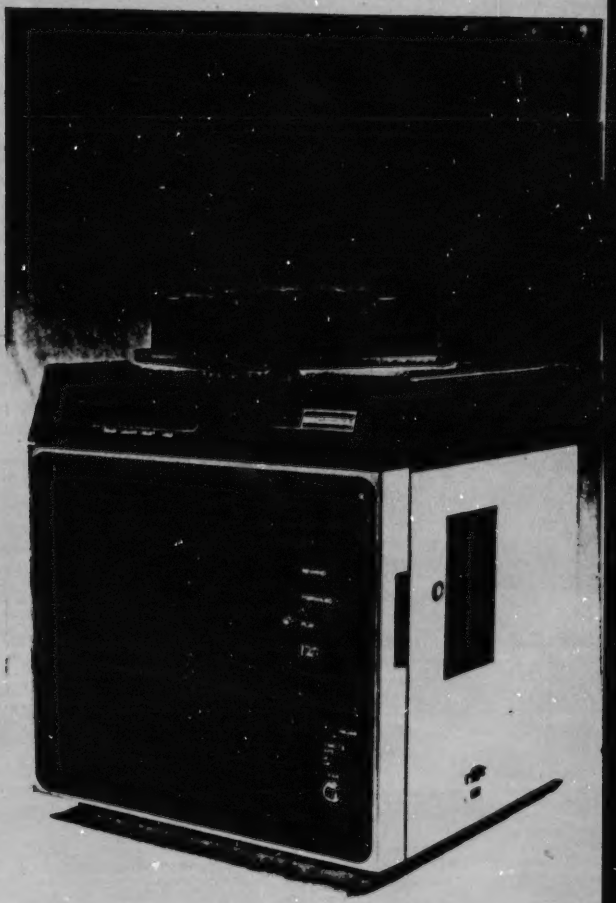


Figure 2-6. Rear Screen Projector.

magnifying lens to examine some portions of images in greater detail.

In the second arrangement a 35 mm rear screen projector was used (Figure 2-6). This arrangement was not as satisfactory as the first arrangement for out students. It appeared that there was too much light glare on the projector's screen.

The greatest disadvantage of using either of these rear screen viewing arrangements is the inability to use microscopic slides.

Projectors for Individual Viewing

A variety of small projectors are available for individualized viewing of two by two slide transparencies or filmstrips. Some of the instruments that are fully automatic allow for sound via the use of cassette tapes. Others are simple battery held devices used to preview slides or filmstrips. While these devices were not investigated by the project, their potential use should not be over looked.

Summary

All of the alternative microscopic viewing techniques described in this chapter can be considered for use with visually handicapped students with useful residual vision. The type of media used with these techniques include microscopic slides, photomicrographs, two by two slide transparencies, filmstrips, pictures, and diagrams. The technique that is used will depend on the materials that are available and the way in which the individual visually handicapped student functions the most effectively.

There are other alternative techniques that are usable with visually handicapped students to study microscopic specimens: the use of physical models and tactile diagrams. While these non-optical techniques are critical for students who function primarily with their tactile modality, the visually handicapped students who have useful residual vision also can use physical models and tactile diagrams. These techniques are described in the next two chapters.

CHAPTER 3 -- Physical Models

Physical models have been used by science instructors for many years with sighted students. Instructors have used physical, or iconic, models to help sighted students understand abstract ideas and processes. Models are used to represent the structure of objects; the relationship between components of a system; the organization of a system; the sequence of events of a process; and other similar kinds of phenomena.

There are two unique benefits derived from the use of physical models. One, the student has an opportunity to handle or observe three dimensional representations of objects and their behavior. This is very critical when students study phenomena that cannot be viewed in their entirety even with optical devices such as a microscope. For example, many students acquire the notion that cells are flat, two dimensional objects after extensively viewing cells with a microscope and in textbook drawing. By handling a physical model of the cell the students may more likely be able to image cells as three dimensional objects.

A second advantage of using physical models is realized if the use of the model involves manipulation. For example, the use of pop-it beads or strips of clay to illustrate the events in mitosis or meiosis permits the student to manipulate the objects to demonstrate what happens to the chromosomes.

But what about using physical models with visually handicapped students? Is it also advantageous for models to be used with these students? The answer is an emphatic yes. It is imperative that physical models be used in teaching biology to visually handicapped students. Models can provide <u>tactile</u> input about phenomena that is gained through visual input by sighted students.

Many visual handicapped students will gain very little, if anything, from the diagrams and pictures

in the textbook, the diagrams drawn on the chalkboard, the films and overhead transparencies, or the specimens viewed in lab sessions. Frequently verbal descriptions are given to these students by sighted persons. Great care should be exercised when this is done, particularly when it is the sole input source. Sighted persons see the whole object first and then break it up into its components. Visually handicapped persons function differently in many situations. They frequently collect information about the various elements first and then put the elements together to form an image of the whole object. Other factors can also influence whether a verbal description has real meaning for the visually handicapped person; a lack of visual memory; poor spatial concepts; and a lack of experiences to understand the words used by the sighted person who is describing what he sees.

Note that it is essential the physical model provides tactile input for visually handicapped students. This is a very easy suggestion to make; and it appears to be a very reasonable one. But most

commercial models available do not provide adequate tactile input for visually handicapped students. The models are designed for use by sighted students.

This means instructors will have to modify the available models or make new ones. While this may appear to be a difficult and expensive task at first, it does not have to be either difficult or expensive. However, it can take a great deal of inguenity. The task should not be viewed in terms of designing something solely for use with visually handicapped students. The models can also be used by sighted students. One should not automatically assume that all sighted students are effective visual learners. Many sighted students may also benefit from having a combination of tactile and visual input.

Several physical models that the project examined are described below. Each model was tested to see if sufficient tactile input was available for use by a visually handicapped person.

Typical Animal Cell

A common commercial model of a typical animal cell was tested with the visually handicapped students. It consists of a cardboard cut-out of a cell which is placed in a hollow plastic ball. It was inappropriate for use with the students.

The project constructed a tactile model to replace the cardboard part of the model (Figure 3-1). Fabric and twine were used to represent membranes; sandpaper to depict the cytosol; BB shot to depict ribosomes to illustrate rough endoplasmic recticulum; a rubber ball with a wedge cut out to represent the nucleus; a small styrofoam ball to symbolize the nucleolus; carved styrofoam rings to illustrate the Golgi apparatus; a marble to depict a lyosome; bundles of balsam rods to represent the centrioles; and depressions to illustrate the vacuole and mitochrondia. After all the components were glued in place they were painted with contrasting colors so students with residual vision could use both their visual and tactile modalities to study the model. The cost for

the materials to make this tactile model was less than three dollars, excluding the plastic ball which served as the exterior part of the cell. The plastic ball from the commercial model that was previously described was used.

Notice that this model could have been made less complex by eliminating selected components. This is the value of home-made models. Only the parts which the instructor wishes to emphasize need to be included in the model. Many commercial models include too much information, therefore including unnecessary "noise" or detractors for the learners.

Mitosis

A commercial model which illustrates the process of mitosis was tried with the students (Figure 3-2). Only two modifications had to be made so they could use it. Aluminum straight pins were inserted into the centromere regions. The head of a pin enables the student to locate the centromeres more easily. For example, in Part 5 of the model (metaphase)

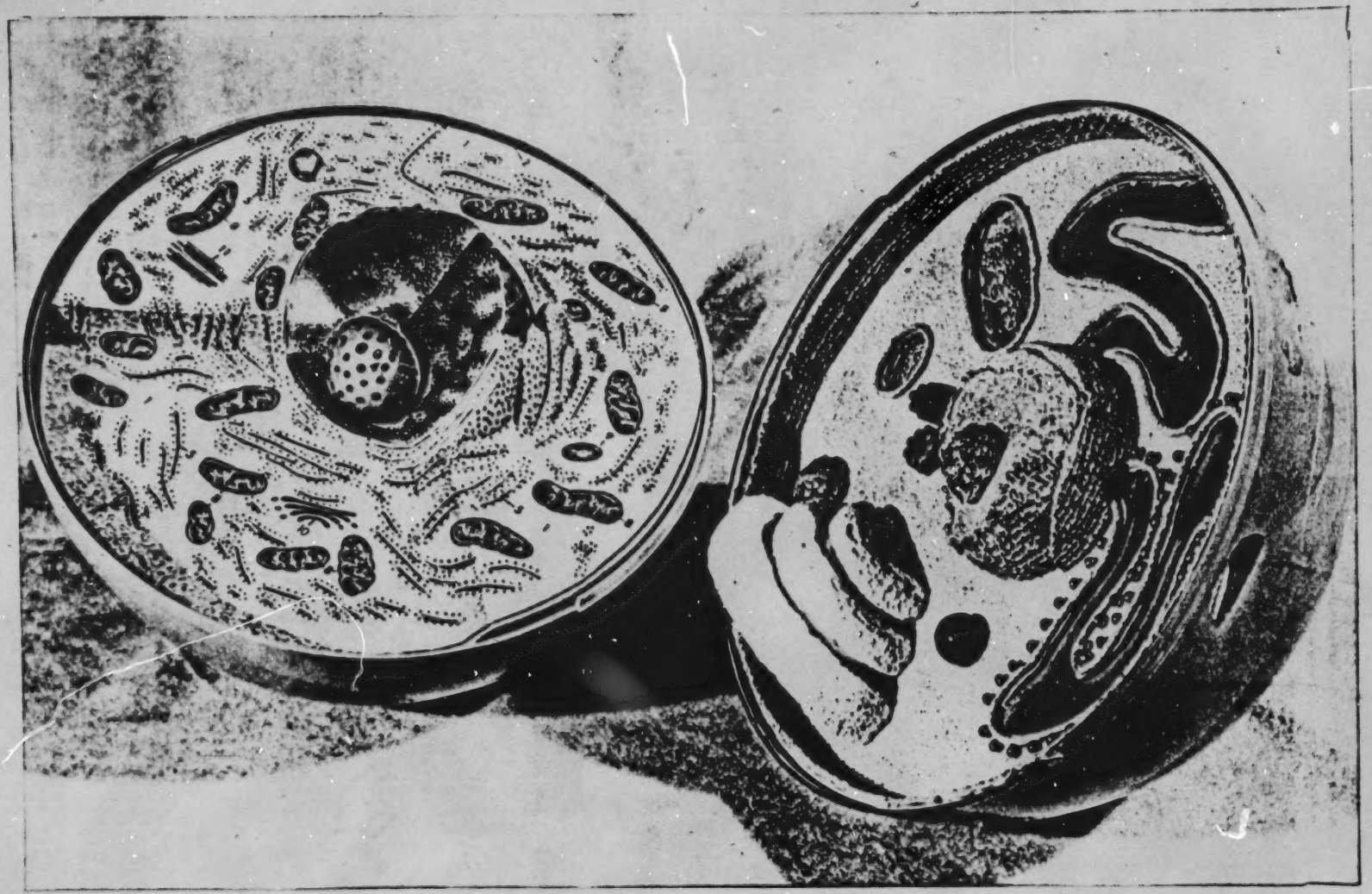


Figure 3-1. Animal Cell.

the students had great difficulty in locating the individual chromosomes before the pins were inserted in every centromere region.

The spindle apparatus is difficult to detect by touch in some parts of the model. Therefore, thin twine colored red was glued to some parts of the model so the spindle fibers could be readily distinguished by touch. In middle prophase (Part 2) and (late prophase (Part 3) twine was glued on the model from pole to pole. In late anaphase (Part 6) and telophase (Part 7) the twine was glued on the model to depict partial spindle fibers in the central portion of the cell between the chromosomal material. In metaphase (Part 4) and early anaphase (Part 5) the model has raised lines connecting the centromeres to the poles that can be detected by touch.

Meiosis

Pop-it beads which come in commercial kits and are used to study mitosis and meiosis can be modified for use with visually handicapped students. For example, red colored beads are normally used to make one two-chromatid chromosome and yellow colored beads are used to make the two-chromatid homologue. To illustrate crossing over between sistern chromatids in meiosis the bead chromosomes are arranged on the table so the sister chromatids overlap. The exchange of chromatid material is demonstrated by switching the appropriate sections of the pop-it beads. For some visually handicapped students it is necessary to modify one set of beads so the difference between the chromosomes can be distinguished by touch. This modification can be accomplished by inserting thumb tacks in all the beads of one color (Figure 3-3). This modification enables the students to trace this aspect of meiosis with their fingers.

The value of models in vocabulary development is illustrated by the use of this model. For example, the use of the word "tetrad" to refer to the positioning of pairs of homologous chromosomes in Prophase I of meiosis is demonstrated tactually for the visually handicapped student. The student obtains

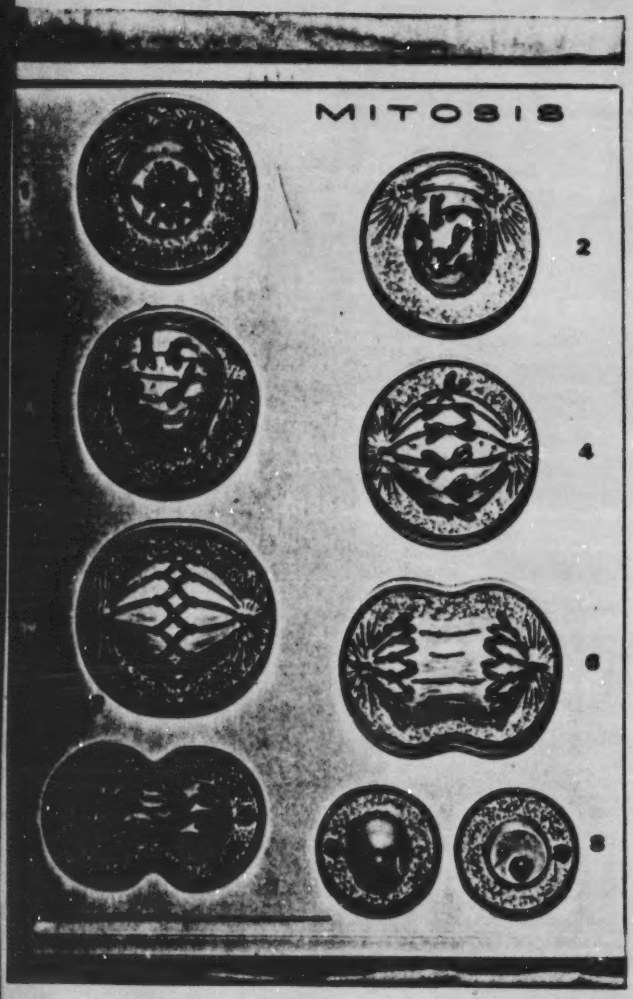


Figure 3-2. Mitosis.

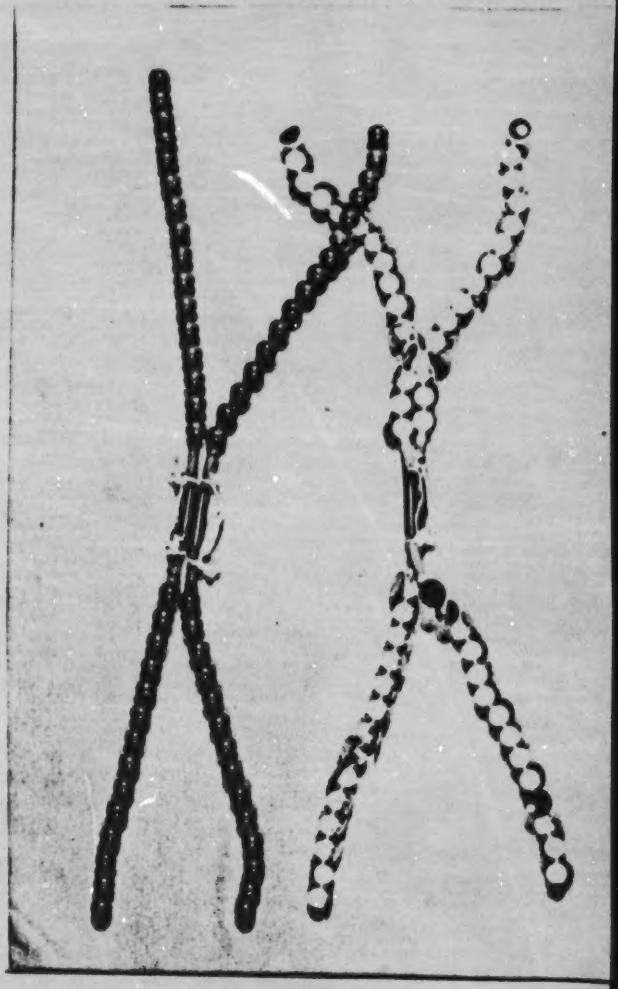


Figure 3-3. Pop-It Beads.

tactile input depicting the meaning of the word by feeling the position of the beads. The sighted student receives visual input to depict the meaning of the word by looking at the position of the beads.

Bacterial Identification

In the regular lab activity the students examine both diagrams and microscopic slides of the different shapes, types and groupings of bacteria. For the visually handicapped students it is possible to make small models to depict many of these characteristics of bacteria (Figure 3-4). The coccus type bacteria is represented by pop-it beads. A single bead with its connector cut off depicts a single coccus cell. Short pieces of dowel with rounded ends illustrate bacilli. To depict a bacillus with an endospore a hole is drilled in the dowel and clay inserted in the hole. Wire is bent in the shape of a cork screw to represent spirillum. A short piece(s) of twine is added to indicate a motile cell.

The various groupings of cocci cells are illustrated with pop-it beads (Figure 3-5). Two attached beads depict a diplococcus arrangement, and a chain of beads represents a streptococcus. In order to build models to illustrate the sarcina and staphylococcus arrangements it is necessary to drill additional holes in the beads. For the sarcina, a cube shaped arrangement of eight beads is required; and for the staphylococcus it is essential to depict a random clustering of cells.

Summary

Physical models that provide tactile input are essential in teaching biology to visually handicapped students. Both commercial models which can be modified and models constructed by the instructor can be used. One disadvantage of physical models relates to the accessibility of them. Students only observe the models while in the laboratory. Later the students have to recall from memory what they observed. To help overcome this problem, tactile diagrams which the

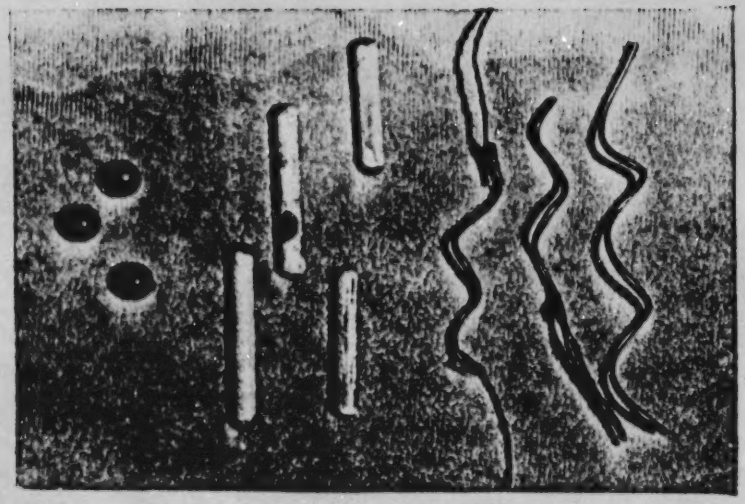


Figure 3-4. Types of Bacteria.

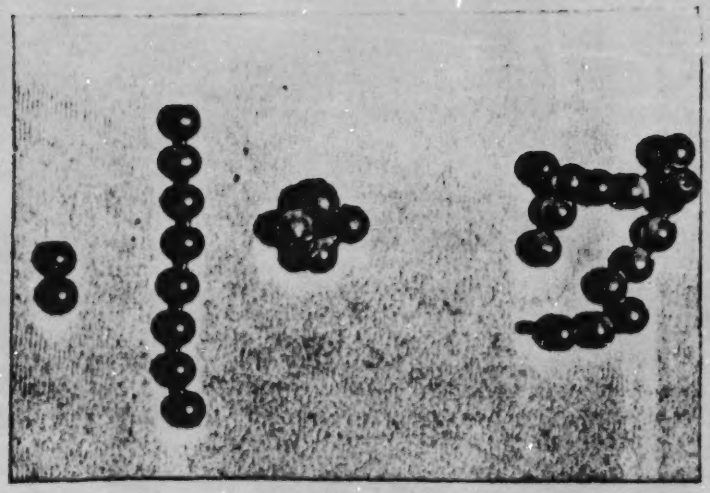


Figure 3-5. Groups of Bacteria.

students could retain were developed. For example, tactile diagrams depicting the different types of bacteria were constructed. The development of the tactile diagrams is described in the next chapter.

CHAPTER 4 -- Tactile Diagrams

While the use of physical models are important, certain needs of the visually handicapped students are not met solely by using physical models. For example, the physical models are handled by the students when they are in class or lab sessions. What happens when the student is not in class or a lab session? Later, how do they review what they observed when they did handle the model? Sighted students can examine diagrams in their books or sketches they made. The visually handicapped students must rely on their memory to recall what they observed after handling the model one or maybe two times. And in many cases physical models are not available or easy to make.

The project investigated the use of tactile diagrams as one means of overcoming this problem. By using tactile diagrams the visually handicapped students could have continual access to the information. To accomplish this the project tested the development of inexpensive reproducible tactile diagrams which the students could retain. Two types of tactile diagrams were tried: ink diagrams which are read by using an Optacon, and raised diagrams which are read with the fingers. Since only one visually handicapped student used an Optacon, the pilot testing of prototype ink diagrams was limited. Extensive pilot testing was conducted with the raised diagrams.

Ink Diagrams

The ink diagrams were designed for use with an Optacon. The Optacon is designed to convert ink print into tactile form. A small camera is moved across the ink print with one hand while the other hand is placed on a tactile array of vibrating rods. The image of the letter or symbol seen by the camera is reproduced on the tactile array of vibrating rods. The reading finger feels this image. For example, if the camera sees the letter "O" the user feels the shape of a circled formed on his finger tip.

Several diagrams of microscopic cells were drawn. Different symbols were used to depict cell components. Figure 4-1 shows a diagram of an onion skin cell. The cell wall is a solid line; the cell membrane is a line of O's; the vacuole is outlined with V shapes; the nuclear membrane is outlined with a broken line; and the presence of the nucleolus is depicted by a X symbol.

Figure 4-2 is an ink diagram of the anaphase stage of mitosis. The cell membrane is outlined by O's; the centrioles are represented by small rectangles; the spindle and astral rays are depicted by X's; the chromosomes are symbolized by solid lines; and the centromere regions are represented by small circles.

The Optacon reader studies a diagram by observing these symbols with the camera. On the basis of trying this technique with one student it was not possible to ascertain its effectiveness. However, the results indicate that it is worthy of future investigation.

Raised Diagrams

The discussion of raised diagrams is divided into two parts: Making Raised Diagrams; and Using Raised Diagrams. This discussion is based on the techniques used by the project and does not represent a complete treatment of the topic.

Making Raised Tactile Diagrams

An outline of the desired diagram is sketched on a sheet of braille paper. Materials to depict different parts of the object being illustrated are selected and glued to the braille paper with Elmer's glue to make a master copy of the diagram.

Two factors are considered when selecting materials to be used to make a master copy. One, the materials have to be resistant to the heat generated by the thermoform machine used to make multiple copies of the diagram. (The American Thermoform Brailon Duplicator, which uses a vacuum forming process, is used to emboss the diagram on a paper-like plastic material called Brailon.) Materials such as paper,

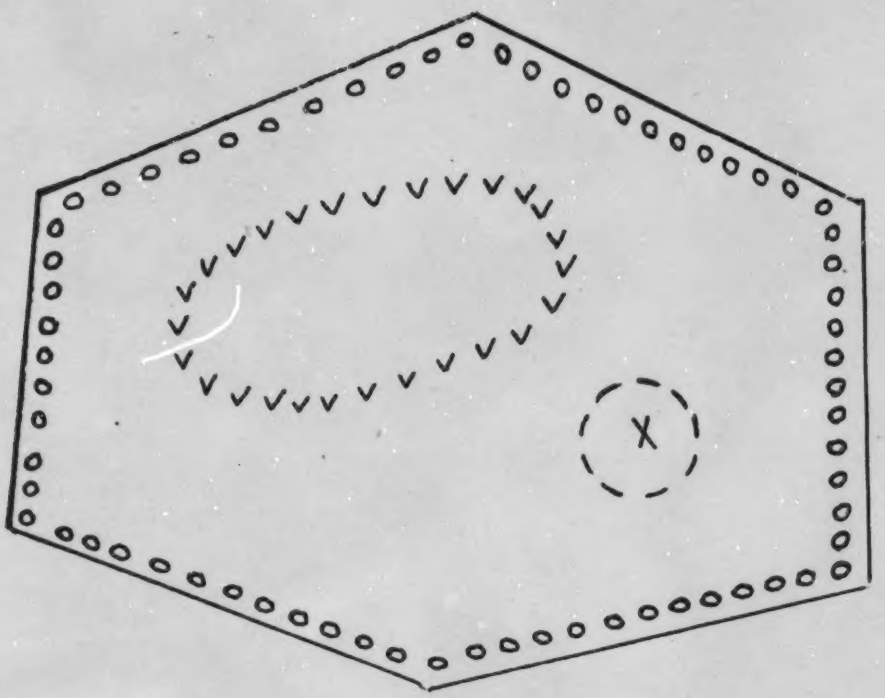


Figure 4-1. Ink Drawing: Onion Skin Cell.

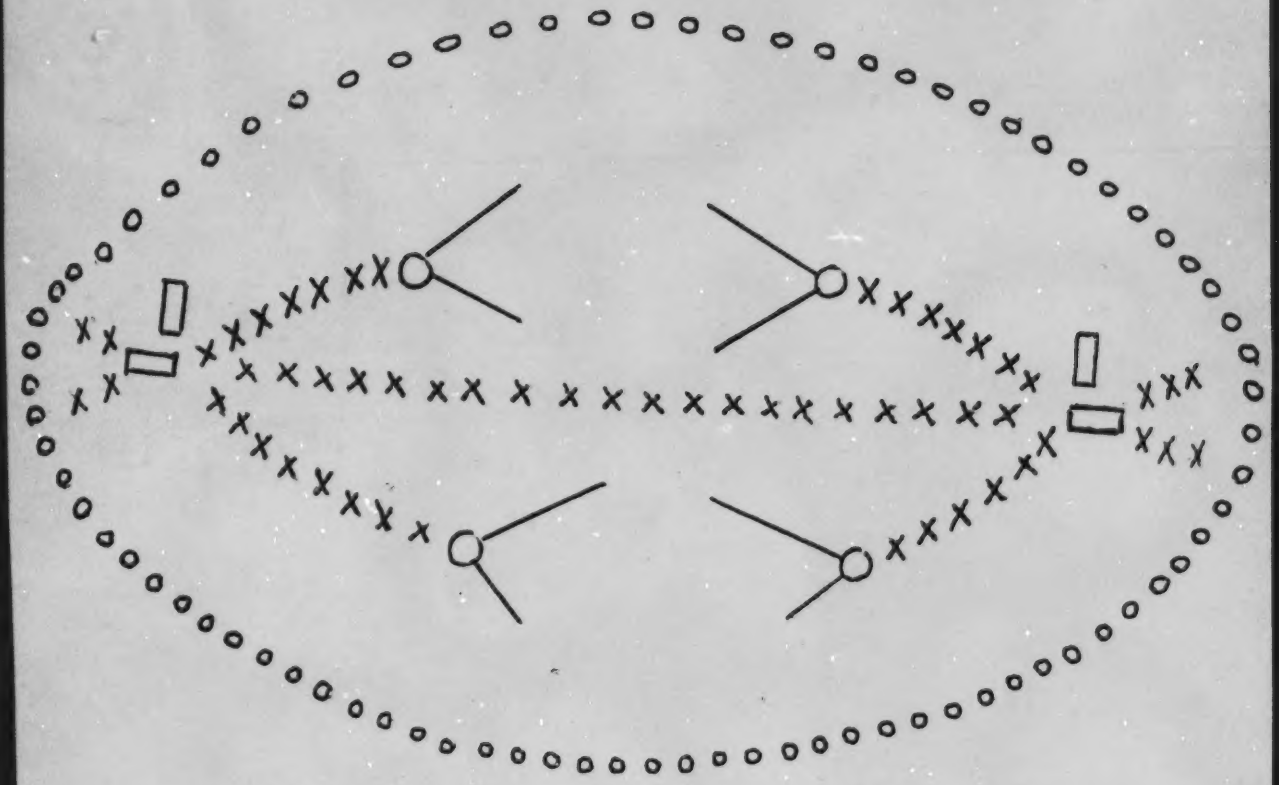


Figure 4-2. Ink Drawing: Anaphase.

wood and metal are useable for symbols, whereas symbols made of clay or glue may not withstand the heat generated by the machine, causing the shape of the symbol to be altered.

The second factor considered in the selection of the materials is the readability of the diagram. To make a readable diagram it is essential to provide ample tactile contrast between the symbols while maintaining simplicity. The finger tips of the reader must be able to easily detect the shape and texture of every symbol in the diagram; and be able to easily distinguish between the shape and texture of different symbols. The simplcity of the diagram relates to the amount of information that is included in the diagram. The complexity of the diagram increases as the amount of information increases. Only the information essential for the learner is depicted in the diagram. Irrelevant details are eliminated as much as possible. In other words, the diagram is composed of the minimum number of essential symbols.

Figures 4-3 and 4-4 show the master diagrams for an Elodea cell and Anaphase I of meiosis. For the Elodea cell strips of balsam wood which produce smooth lines with square edges are used to depict the cell wall. Thick twine which produces a rough textured line with rounded edges serves as the symbol for the cell membrane. The cell's cytoplasm is depicted by a rough texture created by coarse sandpaper; the chloroplasts are symbolized by raised oval shapes made from mat board that have ridges (pieces of soder wire); and the nucleus is represented by a raised circular shape with a smooth surface (mat board), bounded by its nuclear envelope depicted by a thin rough line with rounded edges (twine); and containing a nucleolus symbolized by a single raised dot within a nucleus (a BB embedded in the mat board).

For the diagram of the cell illustrating Anaphase I the centrioles are depicted by small pieces of balsam wood; the spindle fibers are strips of sandpaper; and the chromosomes are either soder wire or

pieces of chain beads; and the centromere region is depicted by a circular shape made of mat board.

Other master copies of diagrams are shown in Figures 4-5 and 4-6.

Symbols that have similar textures and shapes are not used to depict different components of the object in a diagram. If it does become necessary to use similar symbols in the diagram they are not used in adjacent areas. When a series of related diagrams are made the same symbol is used to represent a specific component throughout the series. For example, the same symbol is used for chloroplasts in every diagram of a cell that includes chloroplasts. Or in the series of the diagrams depicting the process of mitosis, the material (strips of sandpaper) selected to represent the spindle rays is reserved for this symbol so that this symbol is standardized for this particular set of diagrams.

Multiple copies of these diagrams are made with the American Thermoform Brailon Duplicator. Figures 4-7 through 4-10 show copies of the diagrams made by

this process. It should be noted that the Brailon paper comes in two grades: light and heavyweight. Diagrams made with heavyweight paper will retain their form better for continual use. However, we found that the lightweight paper was satisfactory for diagrams that were going to be used by only one student. Since the cost of the lightweight paper is much less, the expense of providing copies for every student to retain is reduced.

Using Raised Diagrams

The diagrams used in a particular lab activity are assembled into booklets in the order they are used by the student. Plastic binders are effective. It is essential that the holes be punched in the Brailon paper before the diagram is reproduced on it. Otherwise it may be difficult to insert the Brailon paper having a raised diagram on it into the hole puncher.

In essence, a lab booklet is produced. Along with the raised diagrams it includes a table of contents and other information considered

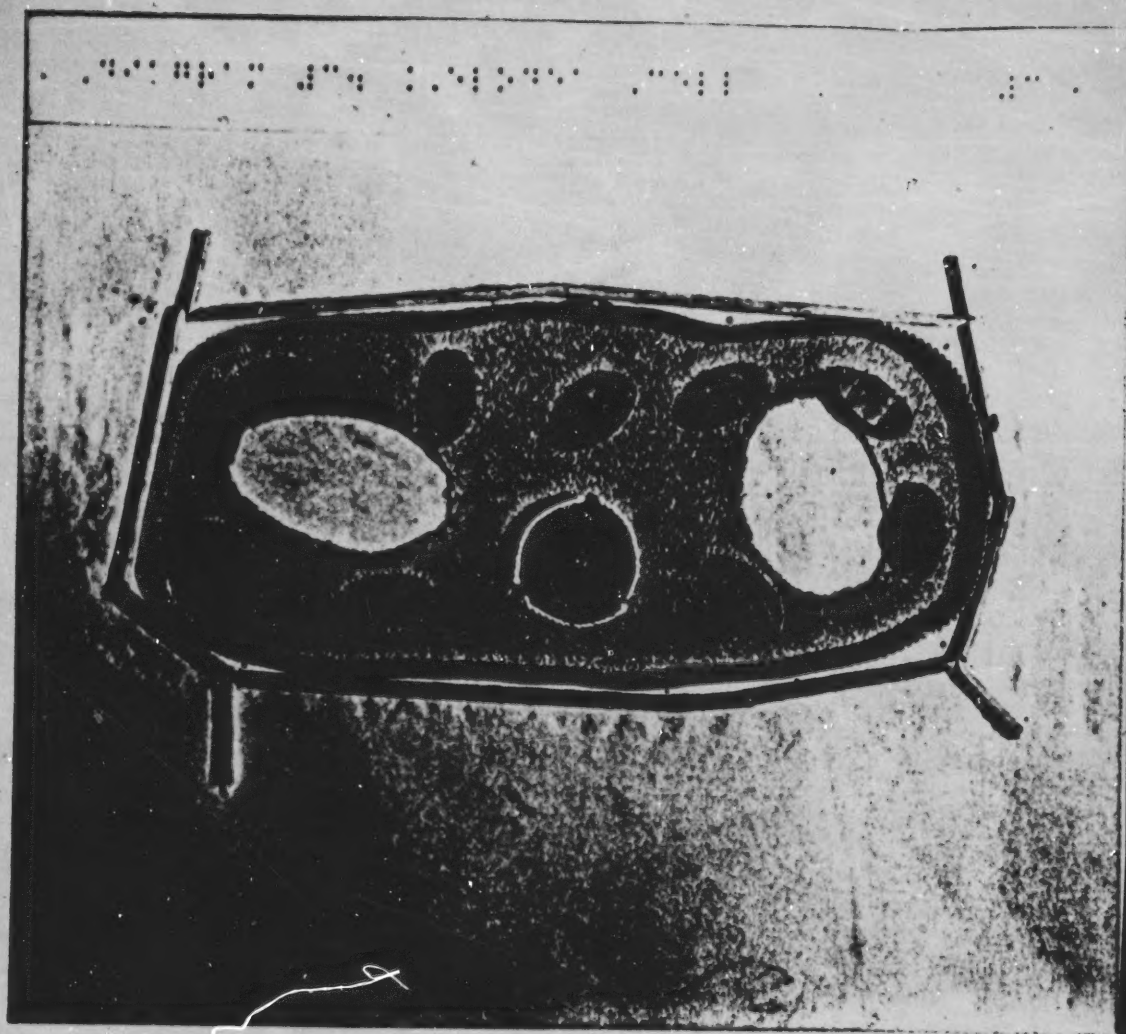


Figure 4-3. Elodea Cell: Master.

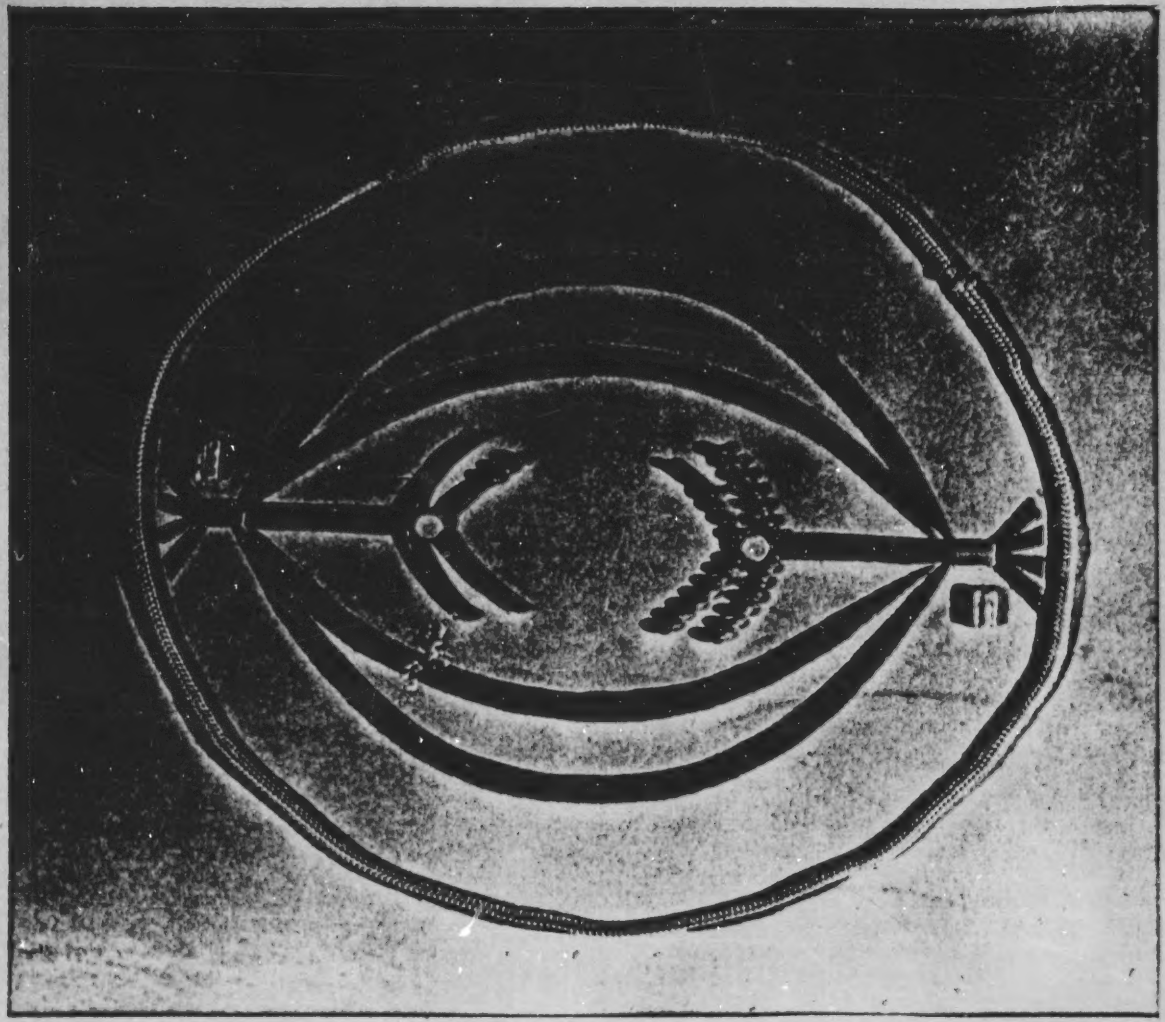


Figure 4-4. Anaphase I: Master.

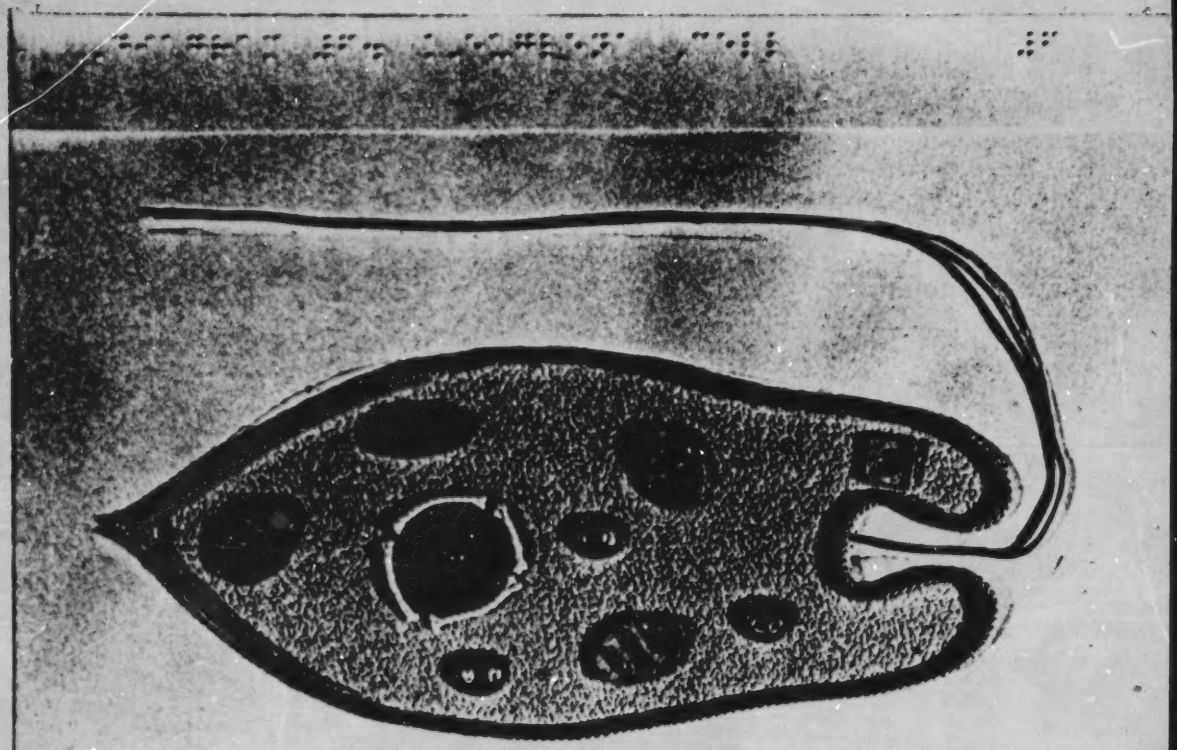


Figure 4-5. Euglena Cell: Master.

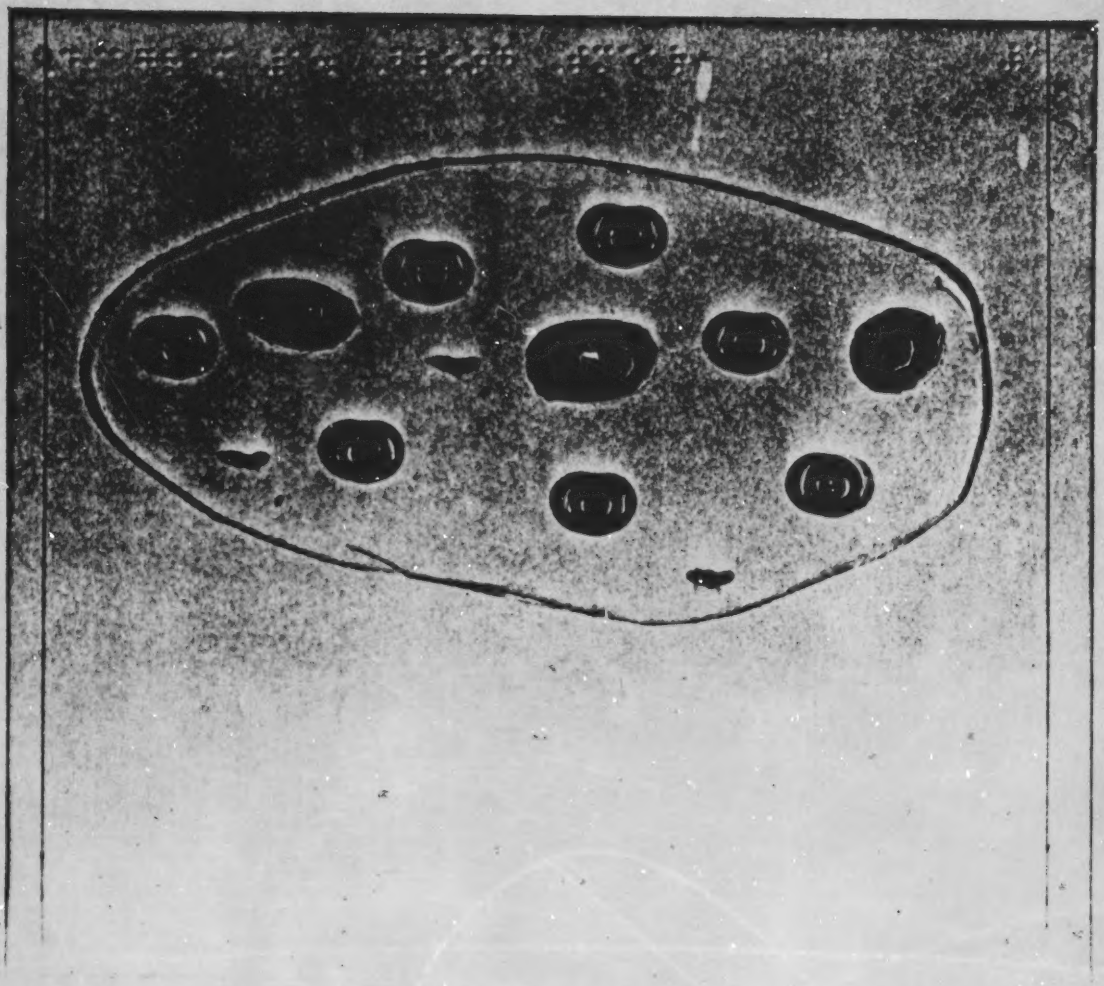


Figure 4-6. Blood Smear: Master

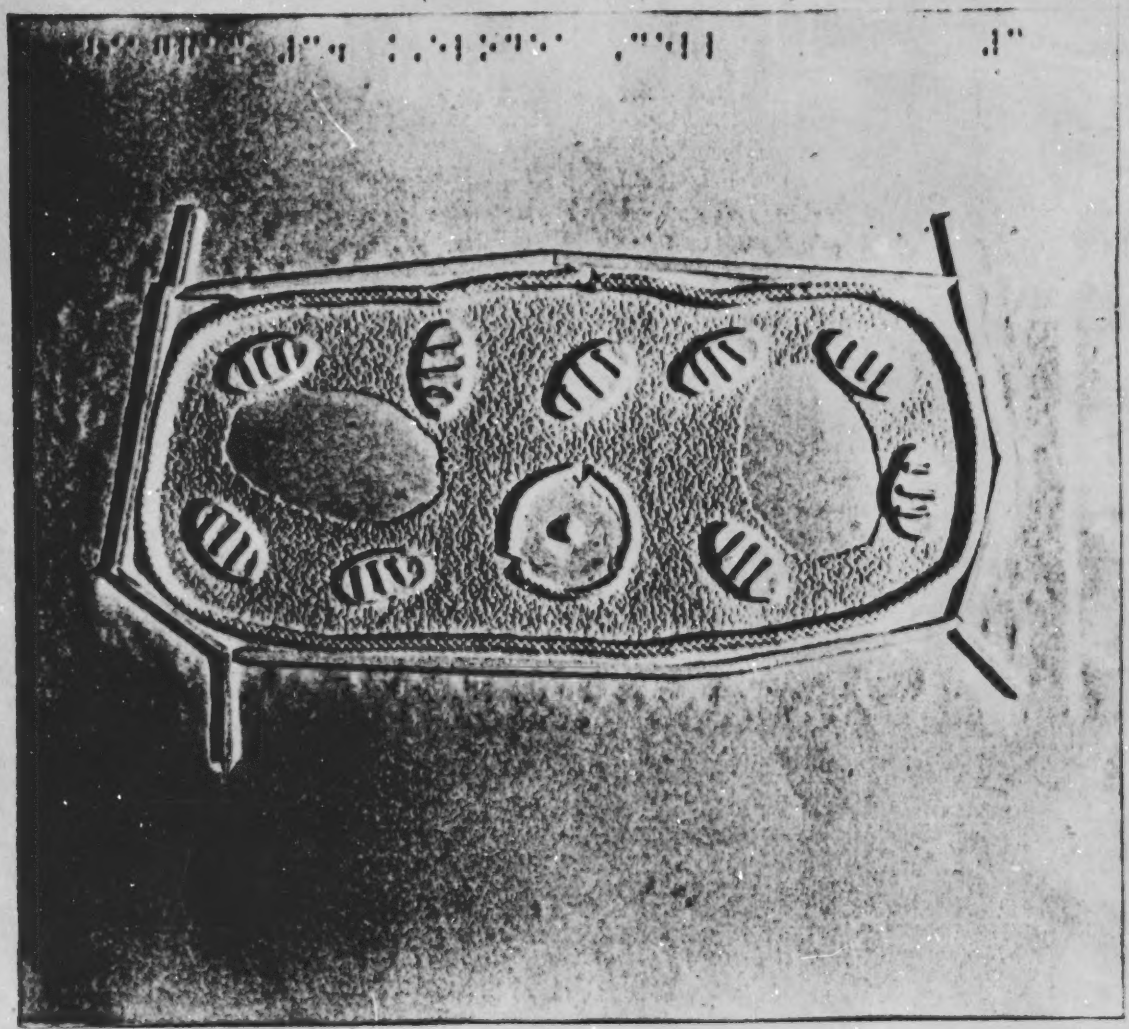


Figure 4-7. Elodea Cell: Copy.

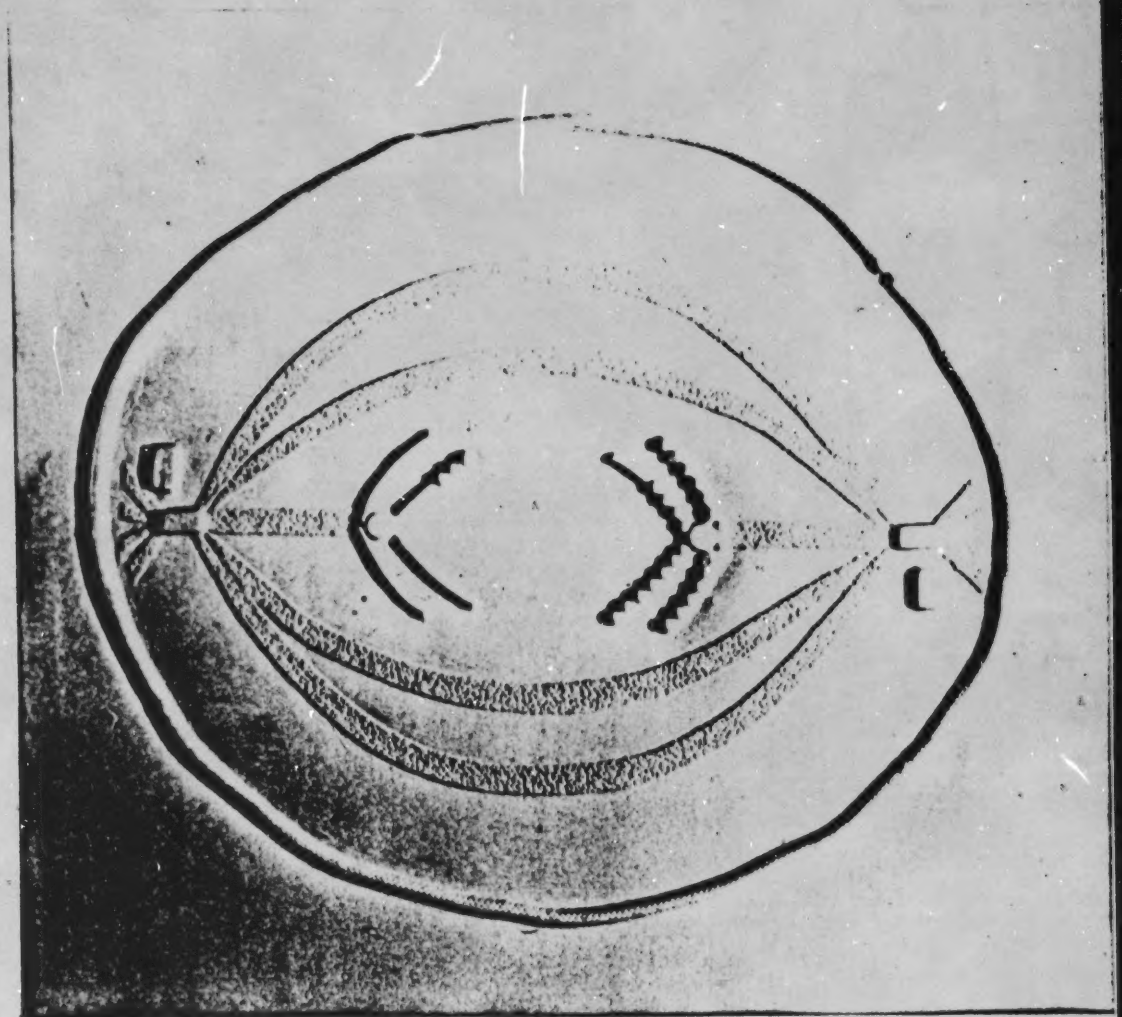


Figure 4-8. Anaphase 1: Copy.

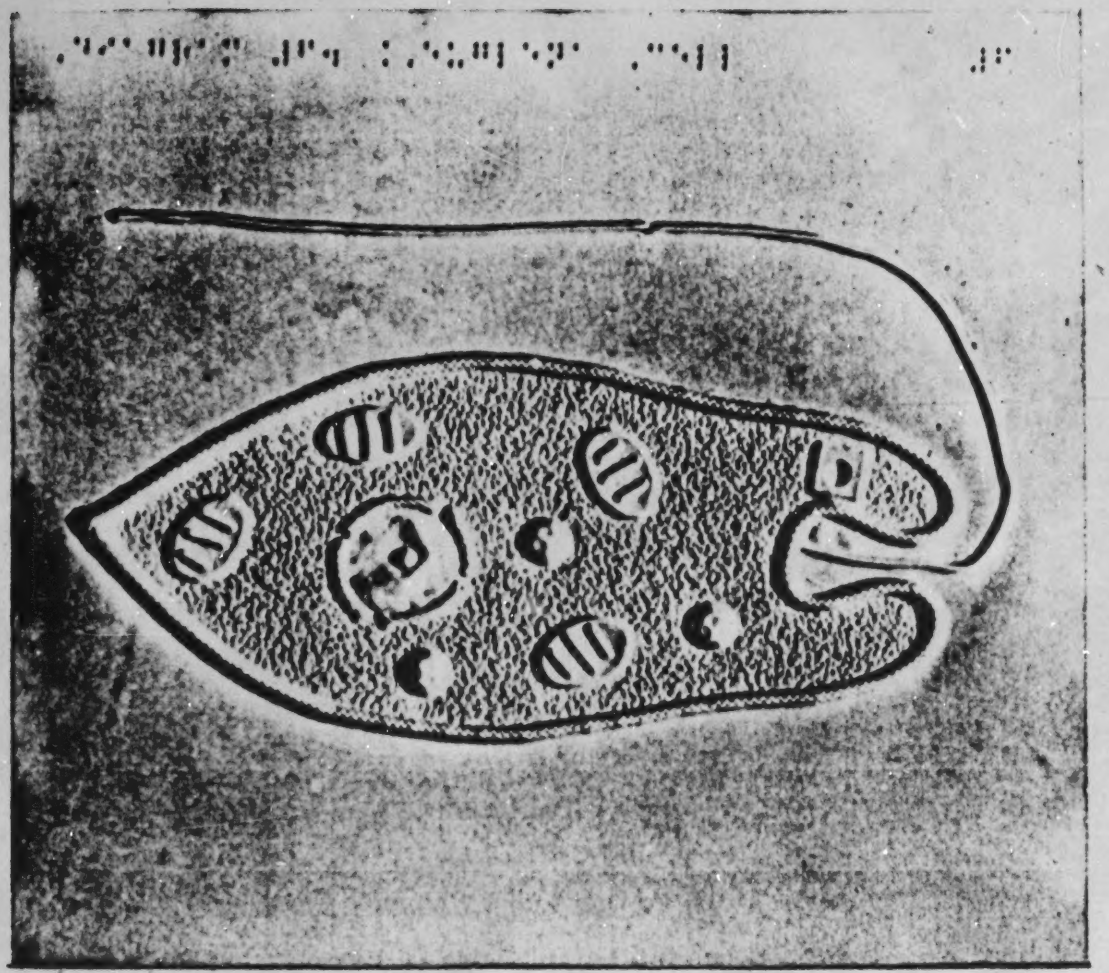


Figure 4-9. Euglena Cell: Copy.

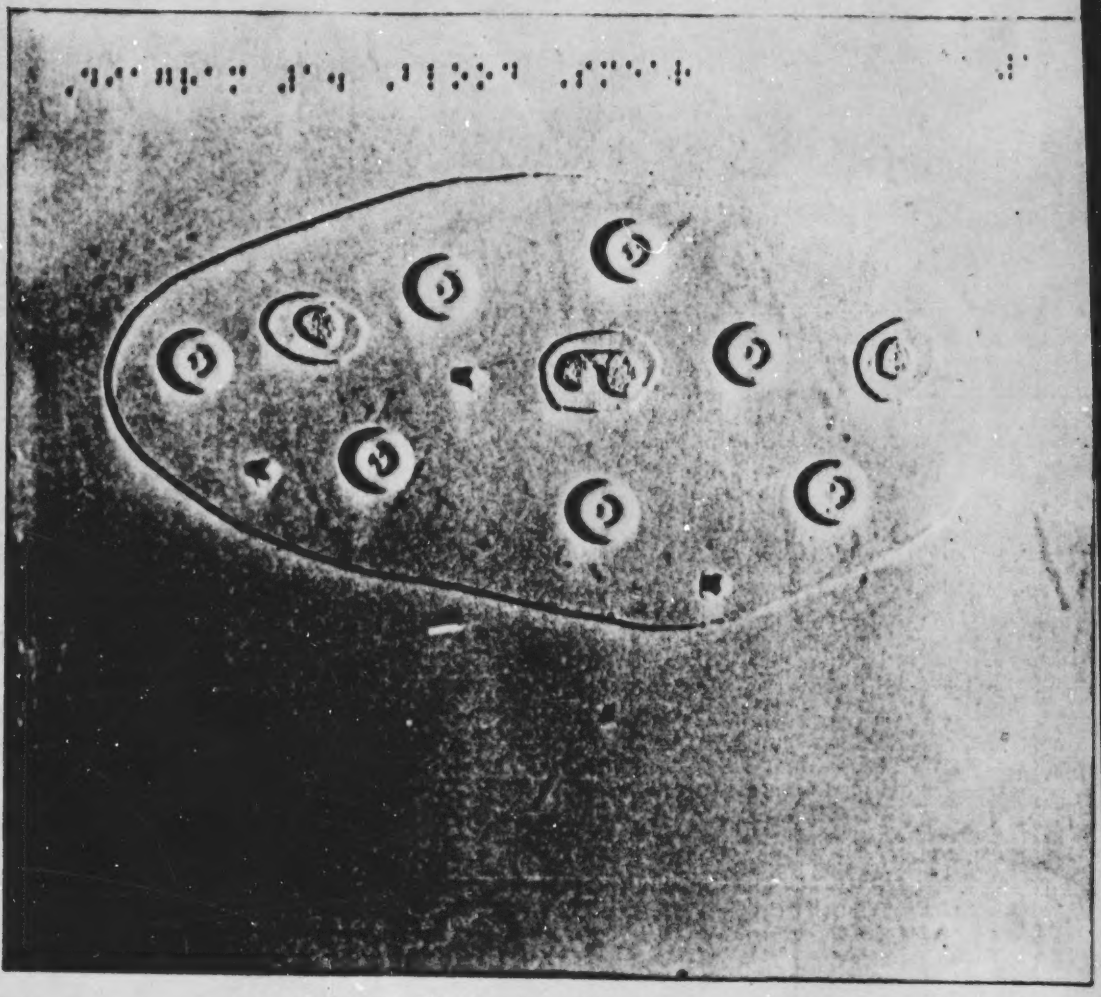


Figure 4-10. Blood Smear: Copy.

essential, all in braille. However, for those students who have functional vision, the table of contents and other information is typed in large print.

For the students who can see colors the diagrams are colored by using permanent type felt markers. The colors help the students locate the symbols more easily. It is interesting to note that the totally blind students will frequently use the color attributes of a symbol when communicating with sighted persons about a specific aspect of the diagram. Colors are selected to provide the most contrast. Two dark or light colors are not used for adjacent symbols. In addition, the colors that are more easily detected are used for the significant symbols of the diagram and those which may be more difficult to detect.

It is essential for both the students and instructors to remember that a raised diagram is not a three-dimensional model of an object. The diagram is only a two-dimensional raised drawing of an object. Different textures and shapes are used as symbols. The symbols are three-dimensional, thus producing a raised diagram. Diagrams should not be viewed as replicates of the real things. In a tactile diagram a dotted line may be used to symbolize a chromosome. In a similar way a circular shaped sign with a large "X" and the letters "R R" on it depicts the presence of a railroad crossing. Or the symbol on a tactile diagram represents a real thing much like the letters "d o g" represent a kind of animal.

Tactile diagrams can serve several functions. Visually handicapped students can use the diagrams to follow class presentations. The use of raised diagrams is particularly advantageous when the instructor draws diagrams on the chalkboard or uses overhead transparencies. Tactile diagrams can also be used in lab activities. The blind student may use a tactile diagram of a microscopic cell as his/her sighted partner uses a microscope to observe the same kind of cell. The two students can compare their observations. In some cases the tactile diagrams may be used to provide alternative lab activities for a handicapped student. Instead using a set of slides to study the

process of meiosis the visually handicapped student can study a series of tactile diagrams. When the tactile diagrams are used for individualized instruction it is necessary to provide a script to the student. The script can be provided in braille, on audio tape, or in large print. If a student uses an Optacon or has access to reading machine, then a typed script (such as this paper) can be used. While it is possible to use any of these techniques, the hearing techniques (audio tape or reading machine) are best so the student can concentrate on using his/her hands to read the diagrams and not the script. The tactile diagrams can also be used to supplement the regular science program by providing visually handicapped students with either remedial or enrichment activities.

Instructors can use tactile diagrams to help assess the achievement of the students. When sighted students are asked to identify a specimen through a microscope, the visually handicapped student can be given a tactile diagram of the specimen to identify. Or if the sighted students are asked to identify the

stage of mitosis depicted by a photograph, the visually handicapped student can be given a tactile diagram of the same stage to identify.

The project worked extensively on the development of scripts so auto-tutorial activities could be used with the visually handicapped students. The development of scripts was one of the most difficult tasks encountered by the project. The scripts cannot be based on textbook descriptions written for visual readers. Generally when people with vision see an object they see the whole object, or its most dominant feature first, and then the details or various parts of the object. Descriptions of objects found in textbooks usually follow this pattern. The following paragraph illustrates this pattern:

> The two fundamental subdivisions of most cells are the nucleus and the living substance surrounding the nucleus, called the cytoplasm. The nucleus is bounded by a nuclear membrane, the cytoplasm by a cell membrane, also called *plasma membrane*. Surrounding the cell membrane in many cases is a cell wall.

The description of a cell presented in this paragraph would not be an appropriate approach to use

for a script to guide a tactile reader. A tactile reader will examine the details of the diagram first. Notice in the above paragraph that the cell wall is mentioned in the last sentence. For the tactile reader this part of the cell will be the first feature he sees with his fingers. The tactile reader examines the details of the diagram first, and then integrates these details to form a mental image of the whole object.

The script which was used to help the students observe the diagram of an Elodea cell (Figure 4-7) is given below. Throughout the script you will notice the word STOP is used. The word "STOP" is used to indicate to the student that it is an appropriate place to stop the tape if he/she wants more time to complete a task before the next task is given.

In this diagram you will examine a cell from the leaf of a Elodea plant which is a water plant. Make a brief exploration of the diagram. You will observe several different textures and symbols: raised lines with a smooth surface and square edges; raised lines with rough surface and rounded edges; a raised circular shape containing a single dot; large oval shaped areas that have smooth surfaces; and small raised oval shaped surfaces with ridges. STOP

Now we will examine the diagram of the cell in detail. First locate the cell wall which goes around the perimeter of the cell. It is the raised line with a smooth surface and square edges. Notice the thickness of the cell wall. At the right and left ends of the top and bottom edges of the cell you will observe portions of the raised line going away from the cell. These portions depict the cell walls of adjacent Elodea cells which are not illustrated in this diagram. STOP

Just inside the cell wall you will find a raised line with rounded edges and rough surface. The line depicts the cell membrane. It may be difficult to feel the membrane in some places as you trace it around the cell. Even with a phase contrast microscope it may be difficult to observe the cell membrane because it is too thin or too closely pressed against the cell wall. STOP

Now we will observe the components within the cell. First notice that the surface area within the cell has a rough, grainy texture. This surface depicts the cytoplasm of the cell. The cytoplasm is the living material of the cell. STOP

At both three and nine o'clock you will observe large smooth surfaces with oval shapes. There are small raised oval shapes with ridges surrounding these smooth surfaces. First locate the large smooth surfaces at three and nine o'clock. These surfaces represent vacuoles. In an actual cell these vacuoles would be filled with a water fluid called the cell sap. STOP

Now examine the raised small oval shapes with ridges that surround the vacuoles and are distributed throughout the cell. These surfaces depict the presence of chloroplasts in the cell. These organelles contain green chlorophyll. Photosynthesis occurs within the chloroplasts. STOP

The last cell component you should observe in this diagram is the nucleus. The nucleus is considered the control center of the cell. In this diagram it is located at six o'clock. It is depicted by a raised circular surface that is bounded by a broken raised line with rounded edges. This raised line depicts the nuclear envelope, sometimes called the nuclear membrane. With a phase contrast microscope it will generally appear as a solid and single membrane. But with an electron microscope it appears as a double layer that is pierced by tiny pores. The smooth surface area bounded by the nuclear envelope represents the nucleoplasm of the nucleus. Within this area you will find a single raised dot. This dot symbolizes the nucleolus. The nucleolus is important in the synthesis of RNA. STOP

We will now summarize your examination of the Elodea cell depicted by the diagram. First you observed the cell wall around the perimeter of the cell. The cell wall of a young plant cell is thin and flexible. As the plant cell matures the wall usually becomes thicker and more rigid. The cell membrane, or plasma membrane, separates the environment within the cell from the outside environment. It helps regulate the passage of materials between the outer and inner environments. The nucleus serves as the control center of the cell. It is bounded by the nuclear envelope. The pores in the nuclear envelope permit only certain molecules to go through, keeping the composition of both the nucleoplasm and cytoplasm consistent. Within the nucleus there is the nucleolus. A nucleus may contain more than one nucleolus. Ribonucleic acid (RNA) is made by the nucleolus. RNA is required for protein synthesis. The vacuoles are common organelles in the cytoplasm of plant cells. The vacuole contains water and solutes, which is called the cell sap. Some vacuoles may also store sucrose or other materials for future use or accumulate waste products. The chloroplasts contain a green pigment, chlorophyll. The chloroplasts use light

energy to convert water and carbon dioxide into sugars, starches and oxygen. This process is called photosynthesis.

This completes your study of this diagram. THE LAST STOP

This script illustrates that the writing style used to describe a tactile diagram is not the same style used to describe a visual diagram. Some techniques that were employed to write this script are noted below.

When a specific component of the diagram is described the location of component is given first. For example, the symbol for the nucleus is not described without first indicating its approximate location in the diagram. In the script the student is told that the nucleus is at six o'clock and then its symbol is described.

At the beginning of the script the student is asked to make a preliminary exploration of the diagram. A sighted person normally sees the whole diagram when looking at it and automatically gains this information

The script includes a summary. A summary helps the student bring all the various elements of the diagram together so he/she can form a mental image of the whole unit. It is a time in which the student is not concentrating on obtaining information via the tactile modality. The kind and length of summary will vary in accordance with the purpose for using a specific diagram. For example, the summary for a diagram included in a series of diagrams depicting the process of meiosis would be much shorter and more specific than the summary given at the end of the script which summarizes the overall process of meiosis.

A critical factor that needs to be considered in writing a script is deciding the amount of information that should be included. This script could have contained much more information. However, it is essential to remember that this is a diagram and not a text. Even the amount of information a sighted student gains by looking at the cell through a microscope is limited. The blind student, as the sighted student, should be expected to gain additional

information from the text. Thus, the writer of an audio script for use with a tactile diagram should avoid the inclusion of large amounts of supplemental information. This information should be placed on tapes or in braille to be used apart from the diagrams.

SUMMARY

Utilization of diagrams which can be read with the fingertips is an alternative technique for providing information to visually handicapped students. By producing diagrams which the students can keep, the students can have continual access to the information. Even though the development of diagrams that can be reproduced was a major task of the project, it does not mean that the techniques for making tactile diagrams on demand and which need not be reproduced are not important. For example, it may be beneficial to an individual student if the instructor can make a tactile diagram to contrast a straight line and a smooth curve on a graph when a problem suddenly arises over the construction and interpretation of a

line graph. Techniques for making these types of diagrams are given in Chapter 7.

While this chapter is concerned with the use of raised diagrams with visually handicapped students, it became obvious to the project staff that it may be advantageous to use the diagrams with sighted students also. A kinesthetic approach may maximize learning for students, regardless if they do or do not have visual impairments.

CHAPTER 5 -- Measuring Techniques

Visually handicapped students frequently are forced into a passive role in the laboratory particularly when the activities include data collection. These students are asked to use the information given to them by their instructor or a sighted partner.

The project investigated various ways that visually handicapped students could make measurements so they could participate in the data collection process. Particular emphasis was placed on measuring liquid volume and determining the mass of an object, since these two skills were used the most in the lab activities.

Measuring Liquid Volume

A variety of instruments that are designed to dispense specific volumes of liquids were tested. Some of these instruments dispense a fixed amount and others dispense variable amounts. The commercially available devices require very few modifications. In some cases only the way in which they are used is altered. Several devices were specifically designed by the project. These devices vary in their simplicity and use.

The measuring techniques described below represent a range of alternative ways that can be used so a visually handicapped student can participate in the data collection process. The particular technique that should be used will have to be based on the specific type of measuring that is required in an activity, the ability of the visually handicapped student to manipulate a device, and the accessibility of the materials.

Syringes are perhaps the least expensive technique for measuring liquid volumes. Two ways of modifying syringes so they can be used to measure a fixed amount of liquid repeatedly were investigated (Figure 5-1). In one modification a piece of wire is attached to the top of the barrel and inserted down into the barrel of the syringe. When the plunger is pulled up

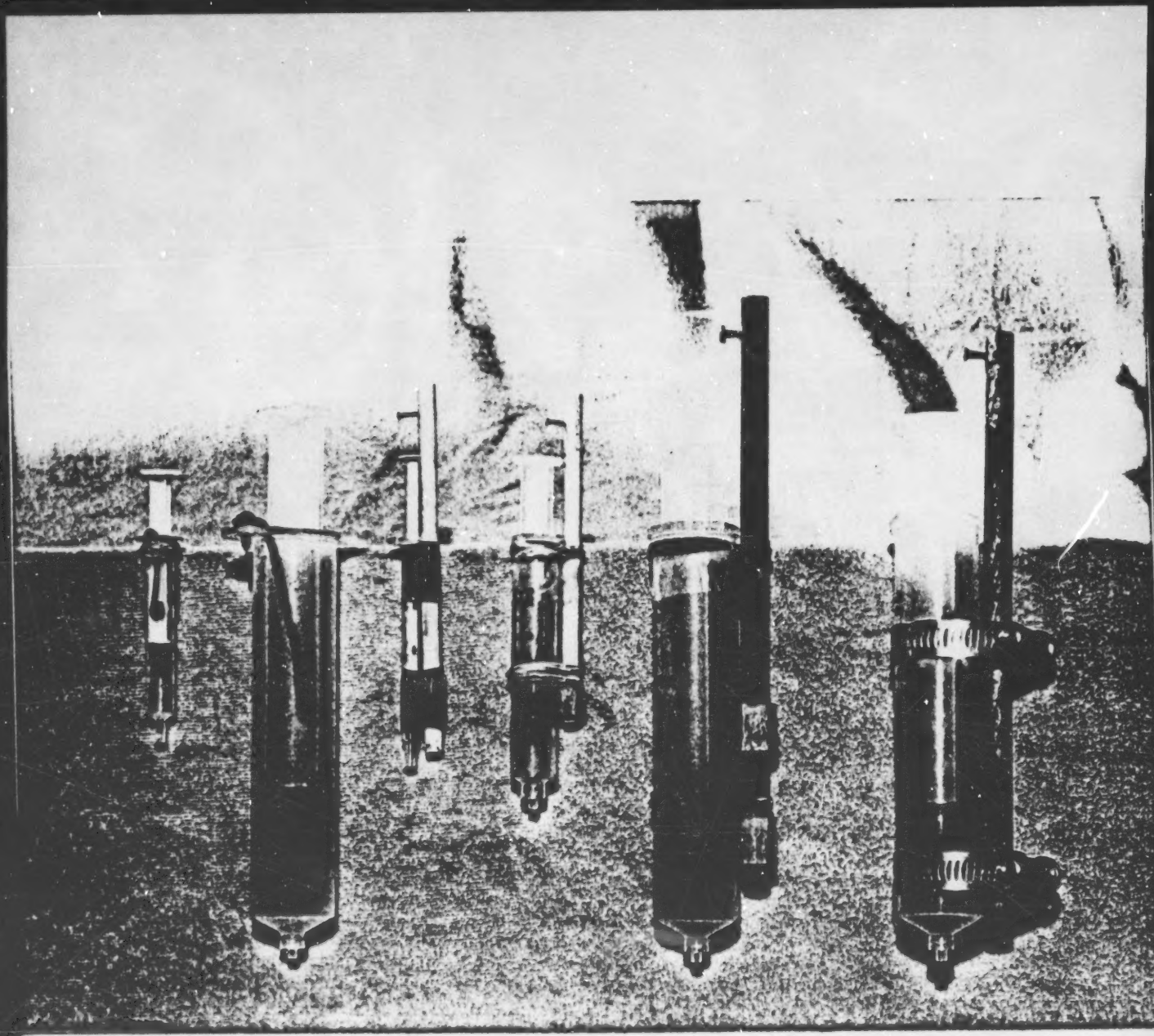


Figure 5-1. Modified Syringes.

the wire will stop it. By inserting wires of various lengths into different syringes it is possible to have a set of syringes that can be used to dispense fixed amounts of liquid. In the second modification a different stopping mechanism is used. A small diameter dowel is attached to the side of the syringe. A nail or screw is inserted near the top of the dowel. When the plunger is pulled up the nail or screw will stop the plunger from being pulled out further. By fixing the dowel stick at a specific location on the barrel, the plunger can be stopped at a predetermined position so a fixed amount of liquid is measured. Again, by having several syringes with the dowel attached at different positions it is possible to have a set of syringes to dispense different amounts of liquid. The dowel can be attached to the barrel of the syringe by rubber bands and tape or hose clamps.

In some activities it is desirable to mount the syringe so it does not have to be held. The syringe can be clamped to a ring stand (Figure 5-2). This technique is preferred when toxic liquids are being

dispensed by the students. As shown in Figure 5-2 the syringe is clamped to the stand so the tube passes through a rubber stopper. Before the student places the container of acid on the ring stand he loosens the clamp and slides the syringe apparatus upward. Tape placed around the post prevents the apparatus from being moved up too far. After placing the container of acid on the stand the apparatus is moved back down. Tape placed around the post prevents the syringe from being moved down too far. Since the tube is guided back down by the rubber stopper, the tube goes directly into the container. After the student fills the syringe he moves it back up the post so he can remove the container of acid and place the container in which the acid is to be put on the ring stand. The container of acid has been set in a block of styrofoam so the student can move the acid without touching the container. In the right hand corner of the styrofoam block there is a hole where the top of the container is placed when it is removed. The container to which the acid is transferred is also

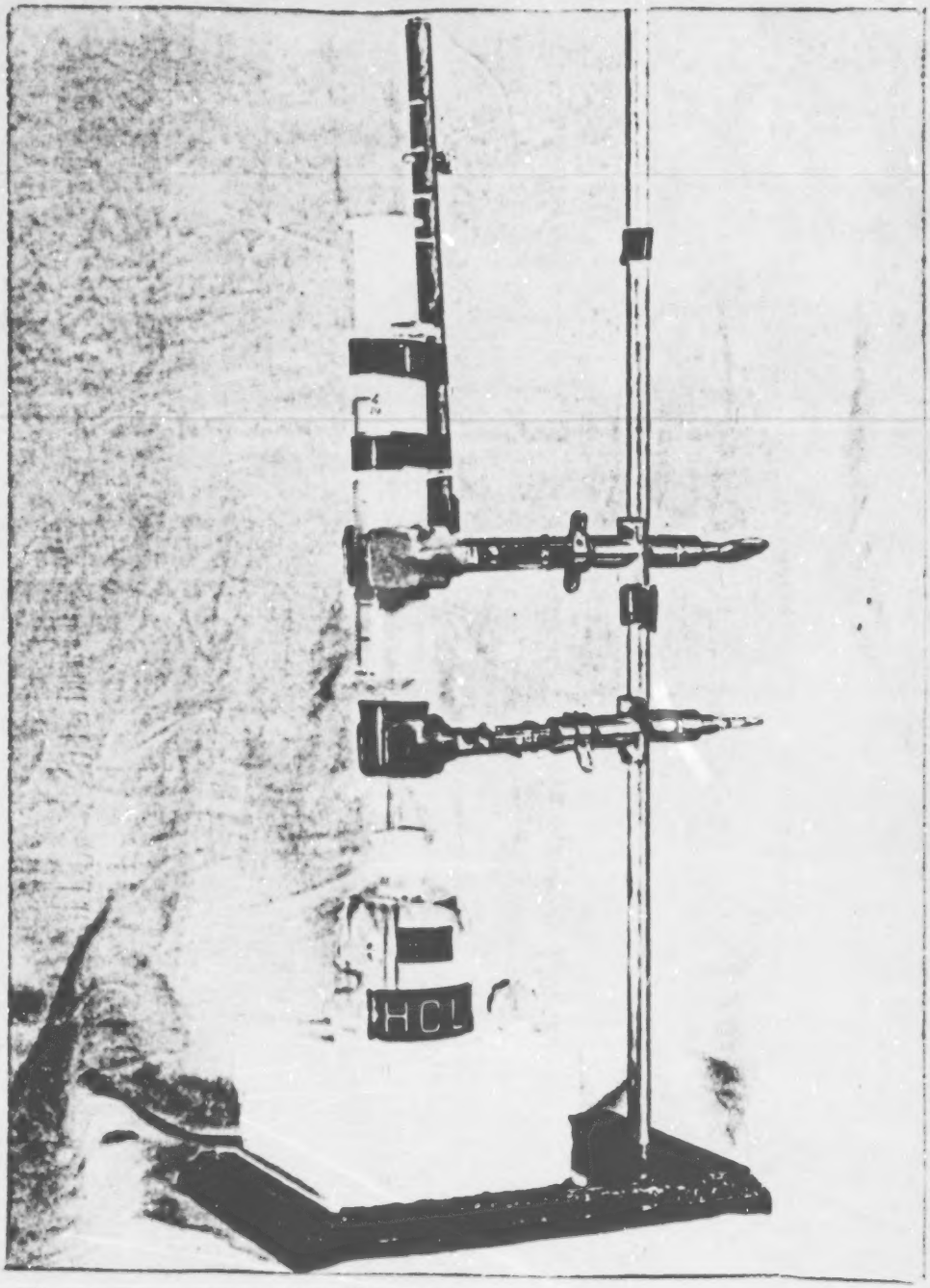


Figure 5-2. Mounted Syringe.

placed in a styrofoam block. On the platform of the stand there is a three sided outline of the block made with strips of balsam. This permits the student to slide the block onto the platform in the proper location. At no time does the student need to place his/her hands under the syringe tube.

The syringe shown in Figure 5-2 is modified so the student can use it to dispense variable amounts of liquid. The dowel stopping mechanism permits 10 ml to 50 ml, in increments of 10 ml, of liquid to be dispensed. Holes in the dowel stick permit a bolt to be placed at different positions so as to stop the plunger at various places when it is pulled up. For example, when the bolt is placed in the second hole up the plunger will be stopped when 20 ml have been measured out. The short pieces of string on the dowel stick enable the student to locate the holes more easily. The bolt is suspended by a string from the top of the dowel stick so it always is in an accessible location.

Two different squeeze type dispensers with fixed volumes were tested (Figure 5-3). One is made completely of plastic. The student gently squeezes the bottle to force the liquid up into the fixed volume dispenser chamber, and then releases this pressure so the excess liquid returns to the bottle. The unit is then inverted and squeezed to deliver the proper volume of liquid. Dispensers are available to dispense 1, 2, and 5 ml of liquid. This device works well with those students who have sufficient vision to detect the rise of liquid up into the chamber so they can determine when to stop squeezing the bottle. Otherwise, the dispenser serves as a fountain.

The second type squeeze type dispenser has a plastic bottle reservoir and a glass dispensing chamber. This dispenser is designed to work in the same way as the previously described dispenser. It is available to measure 1, 2 and 5 ml of liquid. By modifying the way the device is used a totally blind student can also use it. If an empty dispenser is inverted and the tip of the glass tube submerged in

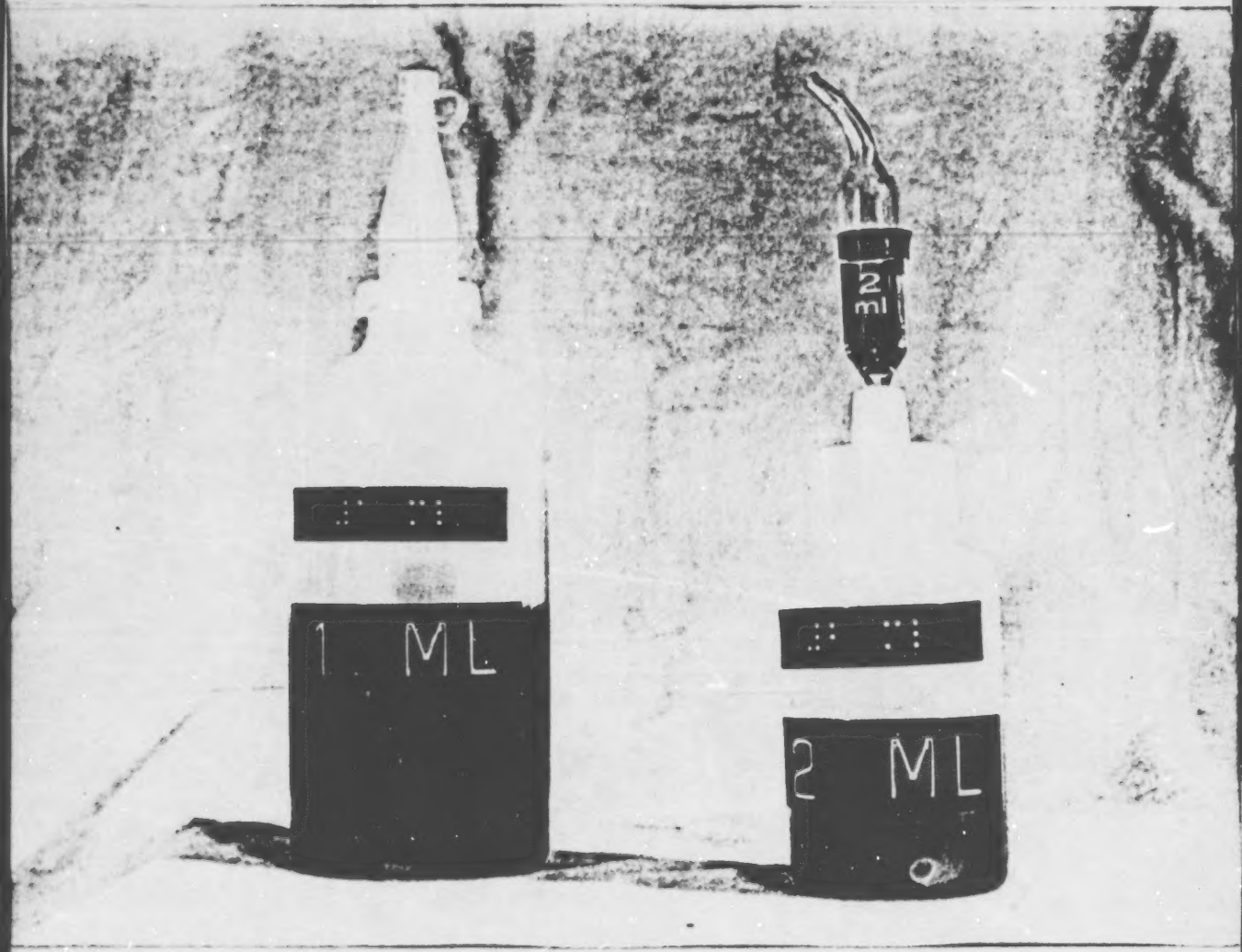


Figure 5-3. Squeeze Type Dispensers (Fixed Volume).

liquid, the student can squeeze the bottle to expel the air. After the air bubbling stops the student releases the pressure and liquid is drawn up into the dispensing chamber. Then the dispenser is inverted so it is upright and the excessive liquid is suctioned down into the squeeze bottle. The student then dispenses the measured liquid in the normal way. By using the dispenser in this manner the student can transfer a specific volume from one container to another.

A squeeze type variable dispenser which was tested is shown in Figure 5-4. This device can deliver up to 25 ml in 5 ml increments. The student squeezes the bottle to force liquid into the cup on top of the unit. Upon releasing the bottle the excess liquid returns to the bottle. Two modifications improve the use of this unit. The original calibrations embossed on the side of the cup are visible only to those with acute vision. The calibrations are reproduced on a white plastic tape in large type, thus making the unit usable by those with residual vision.

To use the device the student slides the measuring cup up or down on the vertical tube to set the volume of liquid desired. With the addition of a piece of soda straw around the vertical tube the unit can be used by students to dispense desired volumes of liquid with more accuracy. Using different lengths of straws the student can position the measuring cup on the vertical tube at the necessary location with more precision than using only his/her residual vision. When non-toxic liquids are dispensed the student can also place a finger along the rim of the measuring cup to detect the rise of the liquid in the cup to prevent accidental spillage.

Two pipet filling devices were tried (Figures 5-5 and 5-6). A pipet is inserted into the device shown in Figure 5-5. The thumb-wheel is rotated to fill the pipet. The liquid is dispensed slowly by rotating the thumb-wheel back slowly. Or the plunger can be dispressed for rapid dispensing. About the same amount of liquid is measured and dispensed each time if the thumb-wheel is rotated the same distance

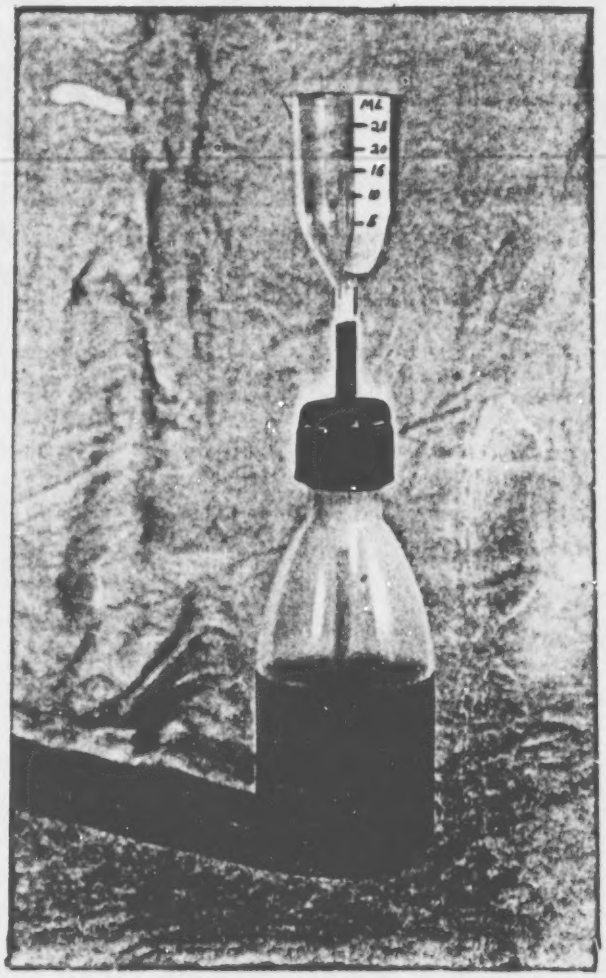


Figure 5-4. Squeeze Type Dispenser (Variable Volume).

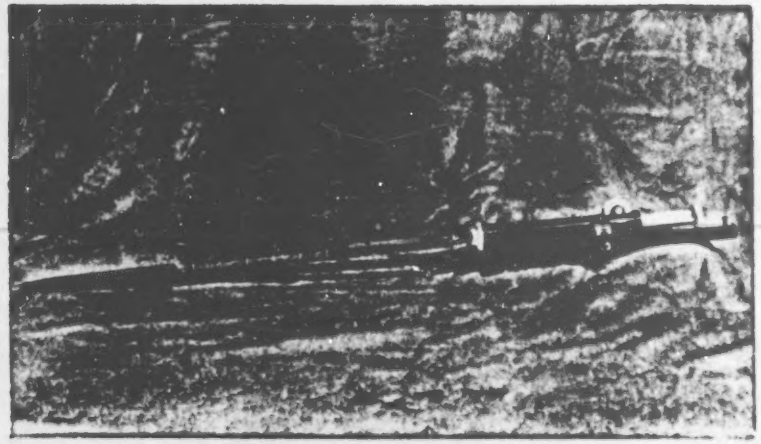


Figure 5-5. Pipet Filling Device (Fixed Volume).

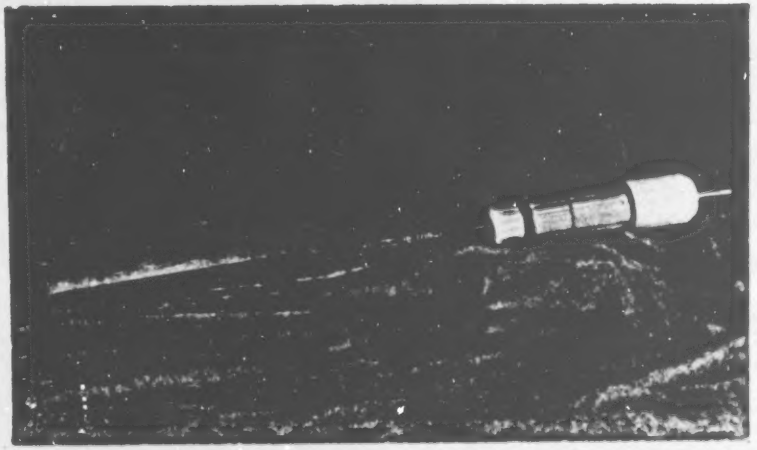


Figure 5-6. Pipet Filling Device (Variable Volume).

each time. A dowel stopping mechanism can be clamped to the device so the top of the plunger is stopped at a specific position each time the thumb-wheel is turned to insure better accuracy. This device is available in 4 size ranges: up to 0.2 ml; 2 ml; 10 ml and 25 ml.

An adjustable volume pipet filler which was tested produced limited success (Figure 5-6). A pipet is attached to the filler. The desired volume, up to 10 ml is set by turning the top cap so the plunger stroke is varied. It was necessary to preset the filler for the students. When the plunger is depressed the air is forced from the pipet and the liquid rises in the tube when it is released. The liquid is dispensed by depressing the plunger again. The students were not able to use the device to consistently dispense the same volume of liquid.

REPIPET Jr. (Figure 5-7) can be used to repeatedly dispense a fixed amount of liquid. Each time the plunger is pushed a specific amount of liquid is dispensed. Dispensers are available to dispense

thirteen different amounts of liquid, ranging from 0.1 ml to 10.0 ml. This device is recommended for use with water, aqueous solutions and diluted acids and bases. In situations where repetitive and precise liquid measurements are required, this instrument works very well for all the visually handicapped students, whether totally blind or partially sighted.

A variable volume REPIPET Jr. is also available (Figure 5-8). This instrument can dispense any volume up to 10 ml in steps of 0.1 ml. The desired volume has to be set initially before it can be used by most visually handicapped students.

An Audicator (Science for the Blind Products) with a liquid level indicator attachment permits a student to measure relatively large volumes of liquid. A standard was made from which the liquid probe is suspended into a beaker (Figure 5-9). The standard is a plastic tube with a groove and several slots cut in its side. The probe fits in the tube and can be moved up and down the groove and laterally into the slots like a bolt of a rifle. The position of each



Figure 5-7. REPIPET Jr. (Fixed Volume).



Figure 5-8. REPIPET Jr. (Variable Volume).

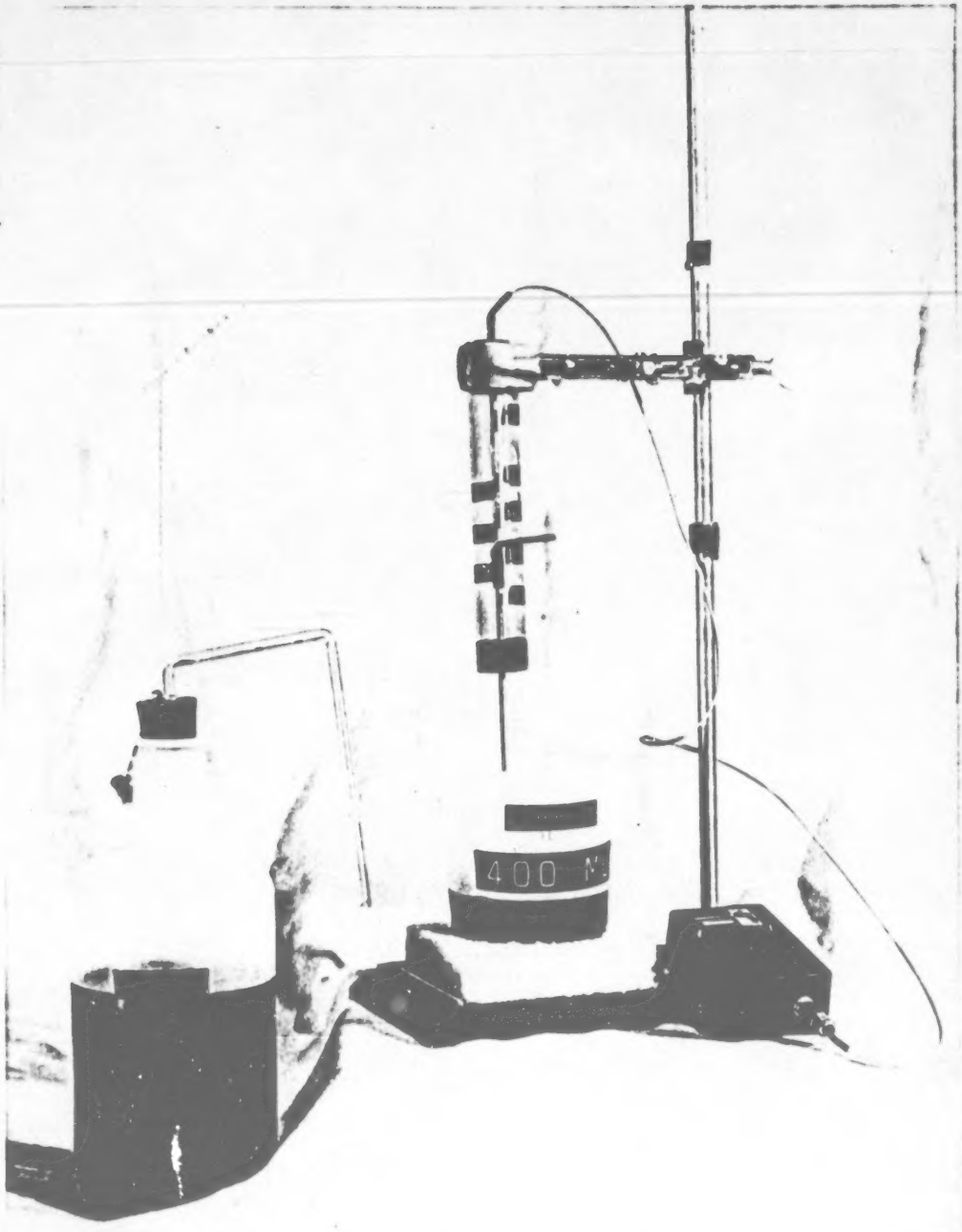


Figure 5-9. Liquid Level Sensor.

slot is calibrated to detect a predetermined volume of liquid in the beaker.

Liquid is dispensed into the beaker until it comes in contact with the end of the probe causing the sensor to emit a high pitched sound. The dispensing bottle is operated by squeezing it, with the plug inserted in the airhole in the stopper. Without the plug inserted, the liquid will not be dispensed when the bottle is squeezed as it is picked up to be moved. The "U" shaped dispensing tube allows the bottle to remain on the table when in use.

It should be noted that this device works better with ionic solutions but the operation is adequate even with distilled water.

Measuring Mass

For calculating the mass of objects an Ohaus Cent-O-Gram Balance was modified (Figure 5-10). The modification does not alter the way the balance functions so it can also be used equally well with non-visually handicapped students. A visually

handicapped students uses the balance as normally used. After placing the object on the pan the weights on each arm are moved to the right so they are seated in the proper notch. The student can determine if the beam is up or down by using his/her fingers. When the student uses the tenths arm, he/she relies on a light sensor to determine when the beam is finally in the balanced position. The light sensor is attached to the balance in such a way that the sensor will emit a sound that varies in pitch to indicate that the balanced position is being approached. (Note: the white L shaped piece of poster board shown in Figure 5-10 is repositioned so it is directly in front of the black piece of poster board so a constant amount of light is reflected from the white poster board toward the light sensor.) The closer the beam comes to a "perfect" balance, the higher the pitch of the sound becomes. When the beam is balanced, the sensor emits a constant high pitched tone. To calculate the mass the student counts the tenths first. Braille dots on clear tape are attached

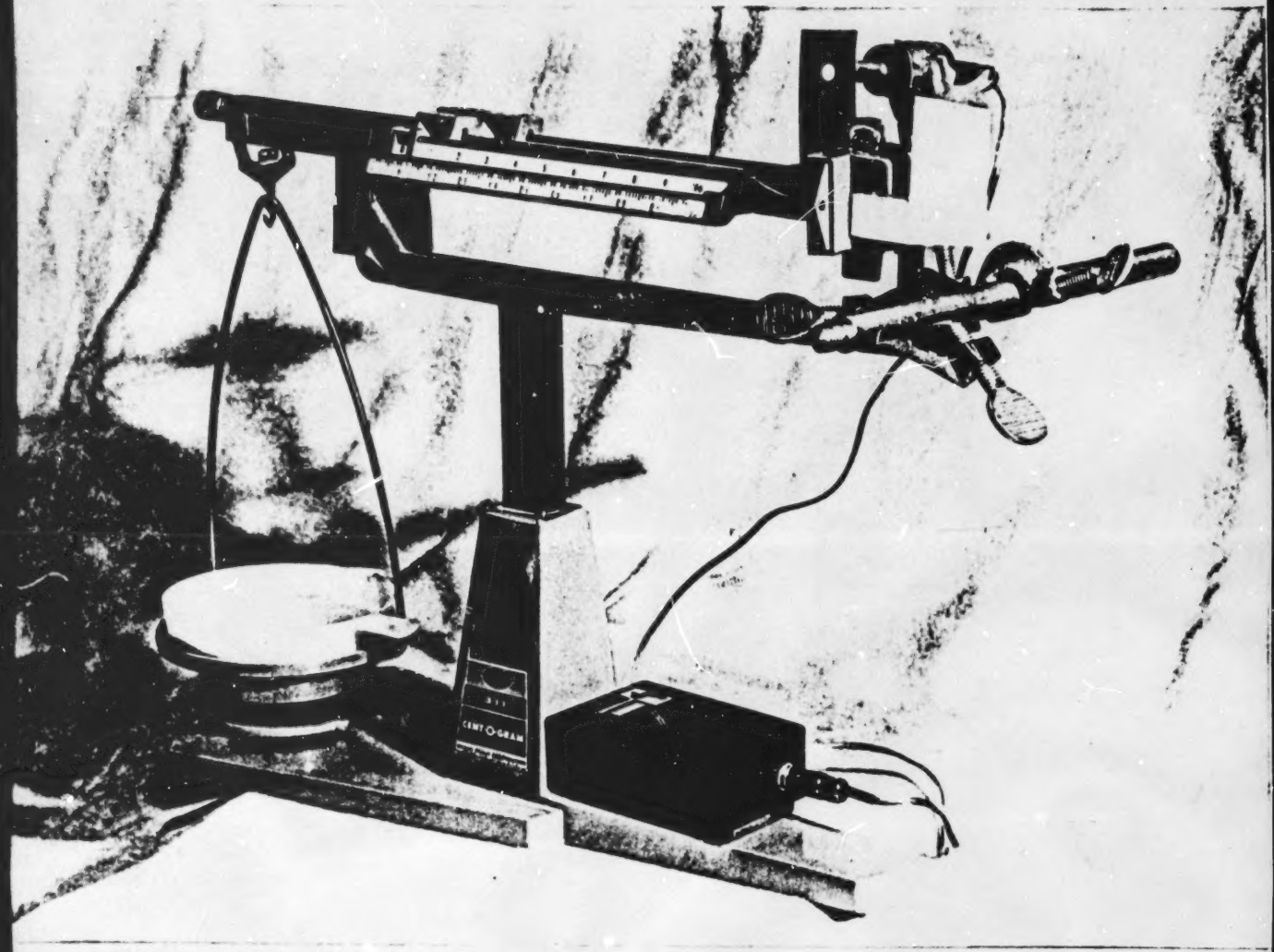


Figure 5-10. Modified Balance.

to the tenths arm so the tenths can be measured and the hundredths extrapolated. A row of three braille dots are located at each tenth mark and one braille dot is located at the .05 marks. For example, the student determines by touch if the tenths weight is between the .20 and .25 or the .25 and .30 gram position. After determining this value the student uses his finger to count the number of notches on each beam to ascertain the unit, tens, and hundreds values of the mass. The notches are filed slightly to make them better defined for tactile reading.

Measuring Temperature

An Aud-a-mometer (Science for the Blind Products) enabled the temperature of substances, ranging from -10° to 110°C to be determined (Figure 5-11). The probe is placed in the substance and after 30 seconds the unit is turned on. The unit emits a sound. The knob on top of the unit is rotated until the minimum amount of sound is heard. Then the temperature of the substance is read by reading the value on the braille

scale at the end of the pointer on the knob. Only the students who were good tactile readers were able to read the braille scale effectively.

With the advent of voice synthesizers thermometers that are capable of giving oral readouts are becoming available. Such an instrument will enable all the visually handicapped students, regardless of their tactile abilities, to measure the temperature of a substance.

Measuring Linear Dimensions

Very few linear measurements were required in the laboratory activities. When linear measurements were made the tactile ruler available from the American Printing House for the Blind was satisfactory (Figure 5-12). Every 5 millimeters and 1/4 inch can be tactual read with the ruler.

Summary

Some suggested measuring techniques for use with visually handicapped students are described in the chapter. For the most part these techniques use

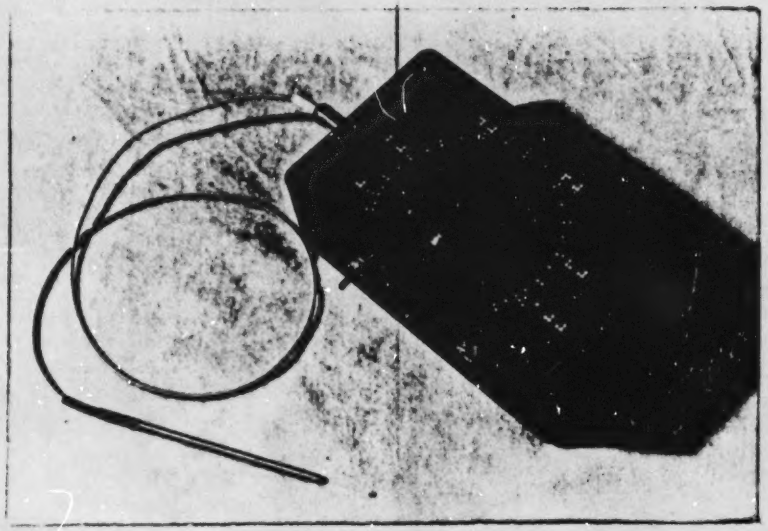


Figure 5-11. Thermometer.

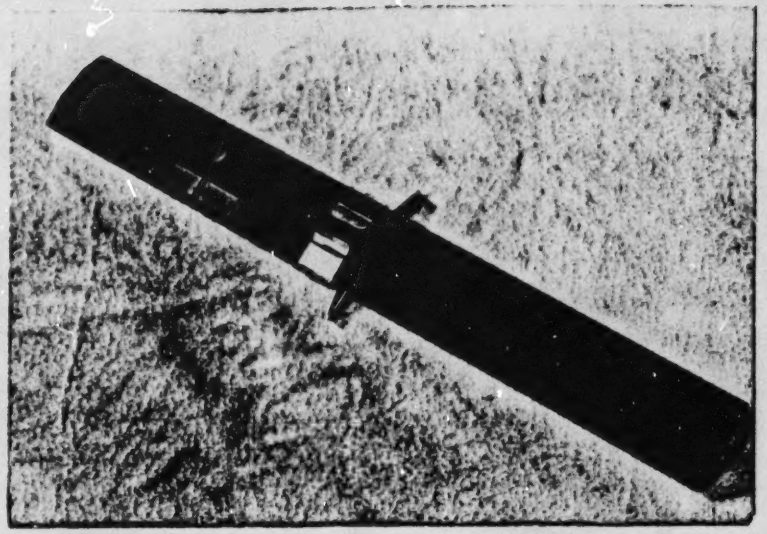


Figure 5-12. Ruler.

inexpensive devices. More sophisticated instruments are appearing on the market. These instruments include devices that use digital readouts and voice synthesizers. Such technological advances will increase the number of visually handicapped students who can participate more directly in the data collection process in the laboratory.

CHAPTER 6 -- Alternative Activities and Materials

In some cases the project found it appropriate to design alternative activities to replace the regular lab activities. Otherwise the visually handicapped student would have to rely heavily on the data provided by the sighted students. For example, one lab assignment involves the study of Drosophila. The visually handicapped students were unable to handle these flies in order ascertain their features. Some of the alternative activities that were considered or pilot tested are described below.

Genetics

Several types of activities were considered as an alternative for the study of Drosophila by the visually handicapped students. The simplest task involved the use of genetic ears of corn. The students can tactually detect the shriveled kernels on a starchy-sweet ear of corn. By using a light sensor they are able to detect a variation in the color of kernels on an ear. However, the exact color of the kernel cannot be ascertained, only that there is a variation. It is a very questionable procedure to have the students try to count the various kinds of kernels on a specific ear to test the expectancy of certain kinds of kernels. It is a very laborious task that produces inaccurate data. The project limited the use of the genetic corn to the collection of data that certain kinds of kernels can be found on an ear; and that there are not equal numbers of each kind of kernel. Then the students are given data that would approximate the results from a hypothetical examination of at least one hundred ears. The students use this data to study Mendelian ratios.

The project also tried several different kinds of seedling plants: tall-dwarf corn (3:1); green-albino corn (3:1); green-albino sorghum (3:1); normal-hairless tomato (3:1); green-albino tobacco (3:1); and green-albino, tall-dwarf corn (9:3:3:1). The following corn seedlings worked best for studying monohybrid

and dihybrid crosses: tall-dwarf; green-albino; and tall-dwarf, green-albino.

The tall-dwarf corn seedlings are used to introduce the 3:1 ratio. The students can distinguish between the two kinds of seedlings by touching the plants. They separate a tray of plants into two groups: dwarf and tall size corn seedlings. After studying the mechanics of this monohybrid cross, the students examine another set of corn seedlings with another trait difference (green-albino) and construct a diagram to explain this monohybrid cross. The technique for constructing this diagram is described in Chapter 7. The students use a light sensor to determine if the leaves of a seedling are dark (green) or light (albino). To verify an uncertain decision they clip off a piece of leaf, rub it in their fingers and observe for a definite odor given off only by the green leaf containing chlorophyll.

The students also examine a tray of corn seedlings for trait differences in both height and color. Upon separating them into groups, they find seedlings

with four different combinations: tall-green, short-green, tall-albino and short-albino. This information is used to study the 9:3:3:1 ratio resulting from a dihybrid cross.

A magnetic Punnett square was constructed so the students could practice manipulating the combinations of genes that could occur in a given cross (Figure 6-1). Tactile symbols are attached to magnetic strips to represent different genes or gene combinations. For example, a rectangular shape with a smooth surface depicts the gene for a dominant trait and the rectangular shape with a rough surface (sandpaper) depicts the recessive gene for the corresponding trait.

The GENETICS MADE EASY kit (National Teaching Aids) is a very visually oriented set of materials for the study of Drosophilia genetics. The kit is used like a magnetic board in that pieces of plastic are stuck to a board. The plastic pieces are manipulated to depict aspects of Drosophilia genetics dealing with body color, wing types and eye color.

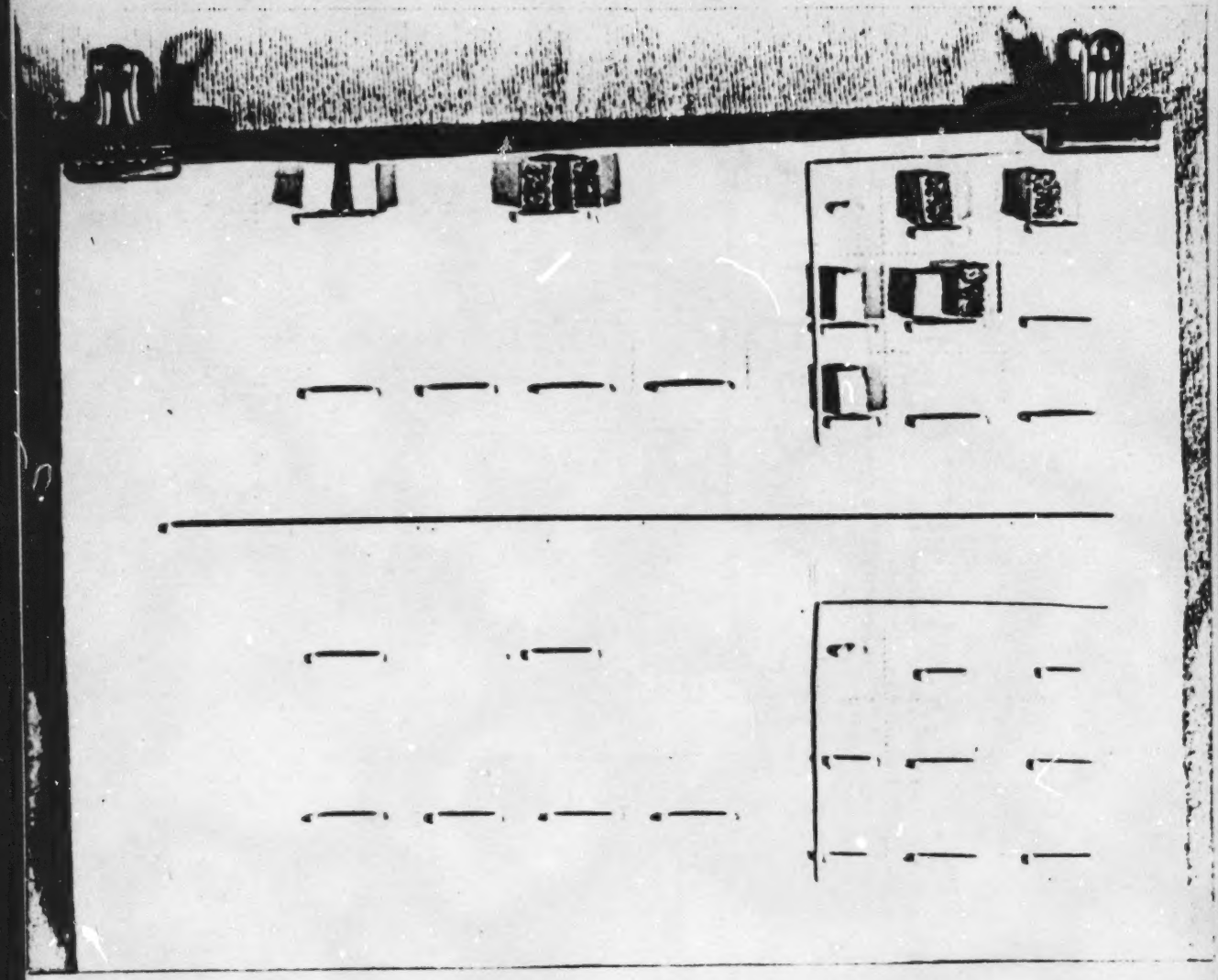


Figure 6-1. Magnetic Punnett Square.

It is possible to modify these materials so the visually handicapped students can study the genetics of fruit flies. The modifications are inexpensive and do not require much time to make. The purpose of each modification is to provide tactile input for the visually handicapped student. The modifications do not hinder the use of materials by the sighted students, but rather the modifications make it possible for the visually handicapped student to work along with the sighted students.

Examination of the plastic body of a fly by the visually handicapped student will yield a shapeless form (see center top of Figure 6-2). The presence of excess plastic around the outline of the body causes it to be shapeless. This problem is solved by cutting away this plastic "shell" around the body. Then the student can distinguish the top from the bottom, and also determine the sex of the fly. Essential information is now available to the student which was previously unattainable. The fly legs dangle after the removal of the plastic "shell" which permits easy detection of the ventral side of the fly. The differences in sex are depicted by the shape of the cut-out body. The female abdomen is longer and more sharply pointed than the male abdomen. In cutting away the excess plastic these differences can be exaggerated slightly for ease in tactile discrimination (see bodies on bottom right and left of Figure 6-2).

The body color traits include gray, yellow, ebony and black. These characteristics are readily apparent to a sighted student due to their vibrant colors. Thin strips of plastic are attached to the body with double stick scotch tape to provide tactile input for the visually handicapped student. These plastic strips are placed on the thorax directly behind the eye socket to symbolize a body color. The body without a plastic strip depicts the grey fly, the dominant color trait, whereas one plastic strip depicts a body with a ebony color, two strips represent a body color of yellow, and three strips depict a black body color. These modifications are

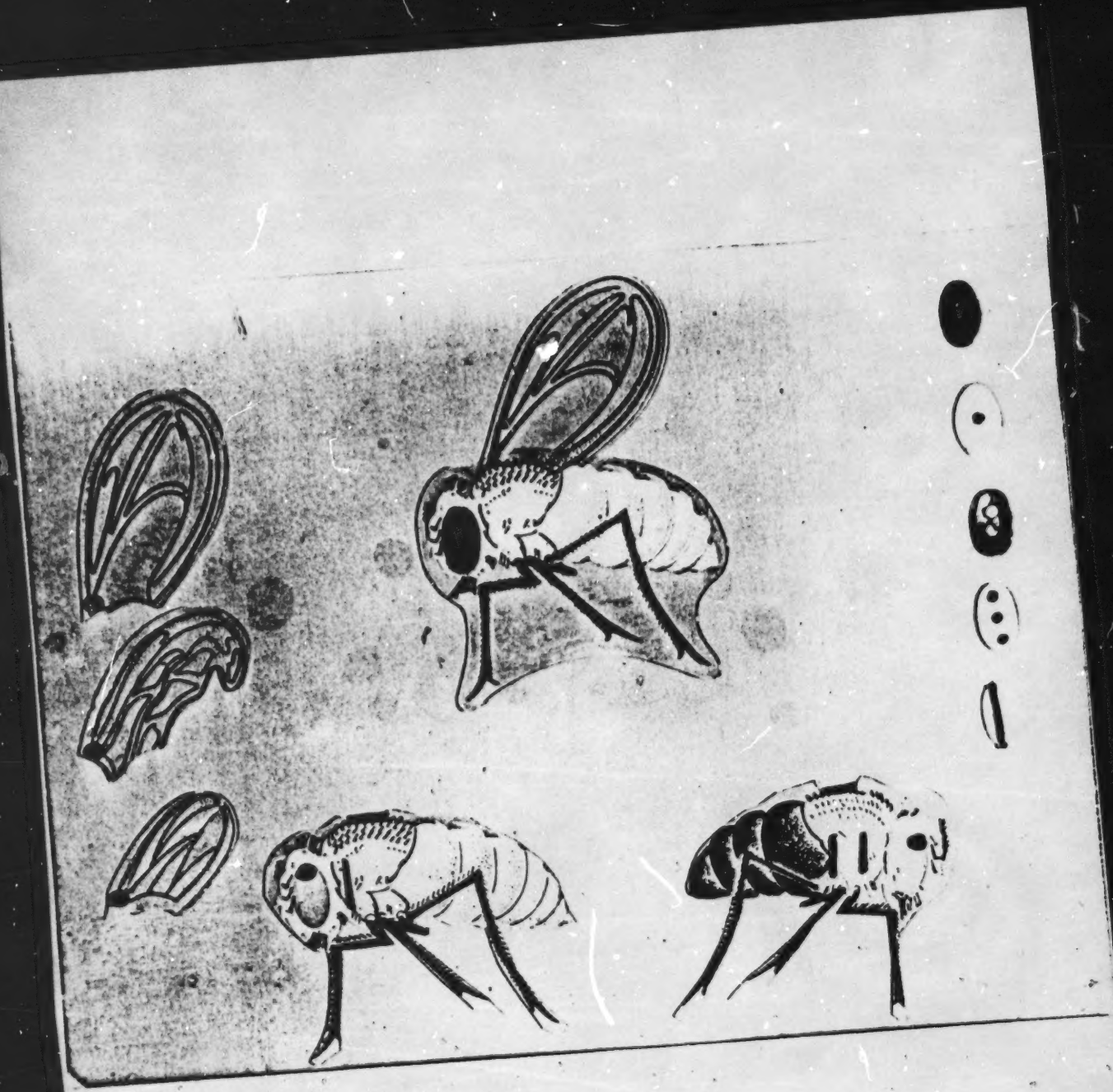


Figure 6-2. Genetics Made Easy, 1.

illustrated in Figure 6-2. Note that the plastic strips appear black. These plastic strips, as well as the other modifications, were colored black so they would be more visible in the pictures. All the modifications are made from the excess transparent plastic that is available after the various cut-outs are made.

Different colors of elliptical plastic shapes are used to symbolize the eyes. Plastic pieces are taped to these eye pieces so the mutant eye colors can be distinguished by touch. For example, one small plastic circle made with a hole puncher is attached to the white eye piece. Two and three circles are used for the sepia and eyeless eye traits. A thin plastic strip enables the student to detect the bar eye. (See right side of Figure 6-2.)

To aid the student in placing the eye piece on the body of the fly a hole is punched in the top of the eye socket. This hole provides the tactile orientation for the placement of the eye piece on the body.

Only one modification is needed to distinguish the wing traits. Both the long and vestigal type wings are distinguishable without modification. The excess plastic is removed from the curly wing so it is readily detected by feel and not confused with the other two wing shapes (see left side of Figure 6-2).

To assist the student in placing the wing on the body two modifications are made. A notch is cut in the body to indicate where the wing should be located. A hole is punched in the lower leading edge of the wing so the student can align the wing with the notch in its proper orientation.

The kit has five plastic pieces to depict four X chromosomes and a Y chromosome. The Y chromosome and two of the X chromosomes can be distinguished by touch without modifications. Two X chromosomes, numbers 2 and 3, have identical shapes. Two holes are punched in the number 2 chromosome and three holes punched in the number 3 chromosome. These holes enable the visually handicapped student to detect each one (see top left side of Figure 6-3).

Small rectangular strips of plastic are used to depict different genes. Color is used by the sighted students to tell the differences among the various gene pieces. So the visually handicapped student can detect the genes for different traits, strips of plastic are attached to the ends of the rectangular shaped gene pieces. A small strip placed on each end of the rectangular gene piece symbolizes the pieces for the wing traits, a strip on only one end indicates the gene pieces for the body color traits and the gene pieces with no strips depict the gene pieces for eye color.

To help the student select the desired gene piece in each of these three categories raised dots are attached to the pieces. Raised dots are made on clear plastic labeling tape and placed on the gene pieces for the mutant traits. For example, one raised dot on the gene piece lined with raised strips on both ends indicates the gene piece for a curly wing; and a similar gene piece with two raised dots indicates the gene piece for a vestigal wing. A rectangular gene piece with raised strips on both ends and no raised dots symbolizes the gene for the dominant type wing. Or if the gene piece does not have a raised strip on either end and no raised dot, it represents the gene piece for the dominant eye color. But if a gene piece without a raised strip on either end has one raised dot it would represent the symbol for a specific mutant eye color. (See top center of Figure 6-3.)

Several other symbols are used in the kit (equals, times, arrows, female, male, etc.). Each of these symbols are made tactile by taping strips of plastic on the symbol to make it a raised symbol. On the symbols for male and female a hole is also punched in the circular portions of the symbols. (See the bottom left side of Figure 6-3.)

The plastic pieces which represent the first three stages in the life cycle of the fly need only one modification. The excess plastic around the outlines of this stage in the life cycle is cut away

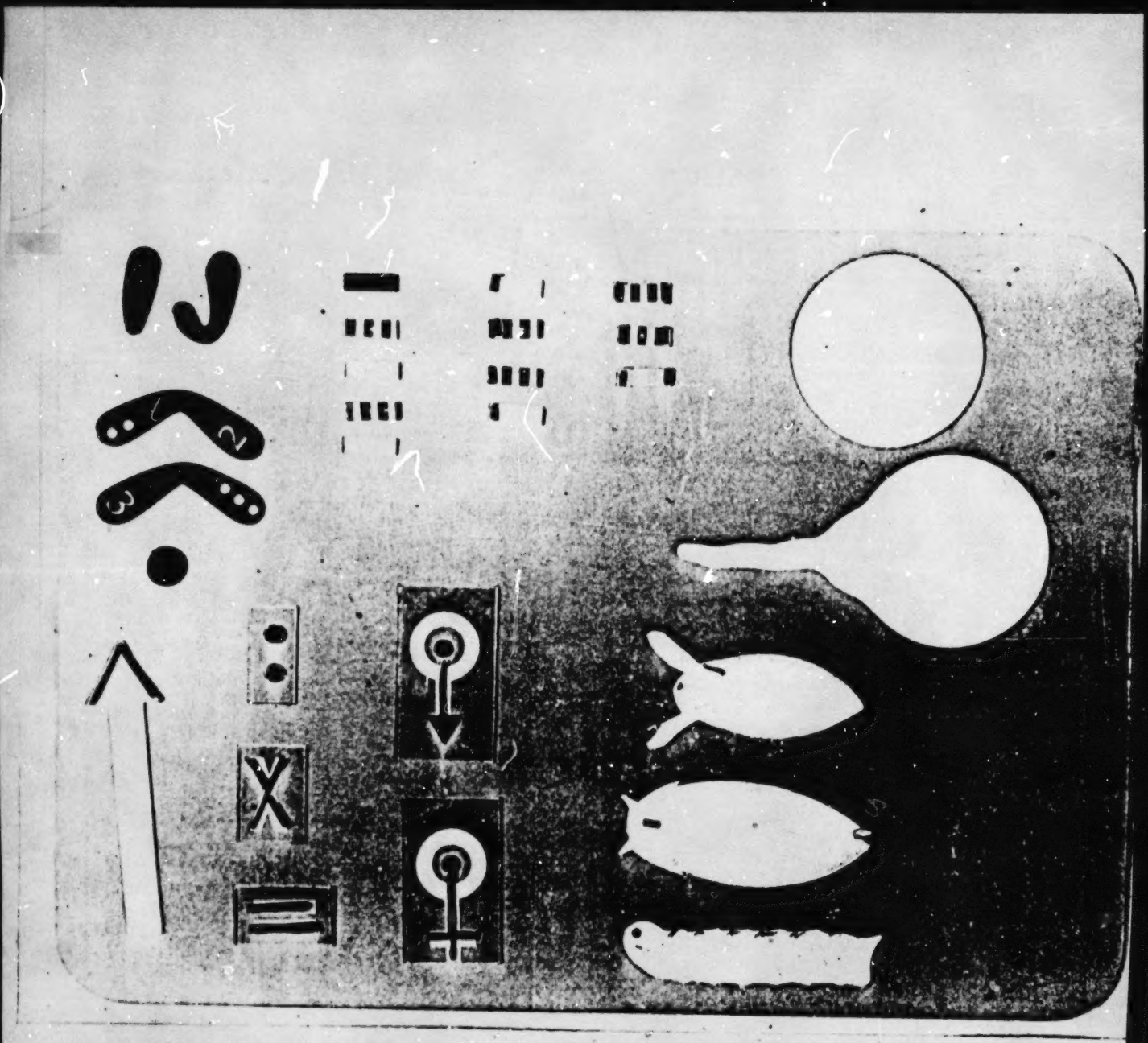


Figure 6-3. Genetics Made Easy, 2.

so they are more readily distinguished by feel. (See right side of Figure 6-3.)

Bacteria

In some lab activities the technique of presenting observational data by tactile diagrams was tried. This technique was used to study the effects of antibiotics on bacteria. In the regular lab activity the students innoculate a nutrient agar plate with a suspension of bacterium and place antibiotic disks on the plate. After several days the students observe the zone of inhibition of growth around each disk to compare effectiveness of different antibiotics on that species of bacteria. Next the students are given several household products that are either antiseptics, germicides or disinfectants to test their ability to inhibit growth of bacteria in the same manner as the effects of antibiotics were tested.

As an alternative activity for the visually handicapped student a tactile diagram was used to present the student with data about the effects of

antibiotics on bacteria. Figure 6-4 shows the diagram. The rough textured surface represents the bacterium plate. The raised circular shapes symbolize the disks placed on the plate. The zone of growth inhibition is depicted by smooth surfaces surrounding the disks. The student measures the diameter of the zone for each disk. In this introductory diagram the diameters of the zones are exaggerated. The students are made aware of this exaggeration. The student observes no growth inhibition around the disk at twelve o'clock. The size of the zones of inhibition gradually increases for each disk going clockwise around the bacterium plate.

So the students can compare the results of using different household products on bacteria tactile diagrams are used to present the data they might have obtained if they had done the activity. Figure 6-5 shows the tactile diagram used to depict the data. Notice that the entire bacterium plate is not presented. Rather only the area of the plate containing a disk is given. By measuring the diameters of the

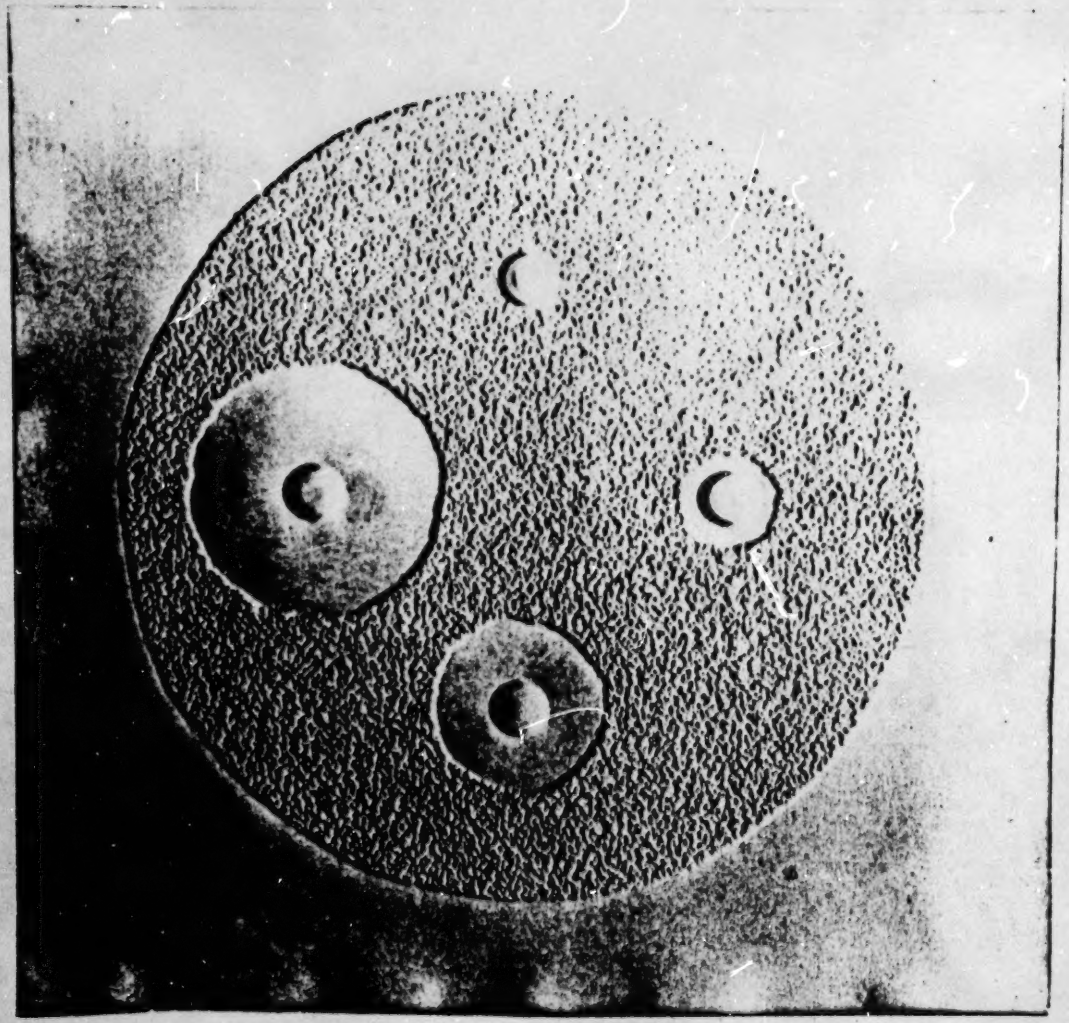


Figure 6-4. Bacteria Plate 1.

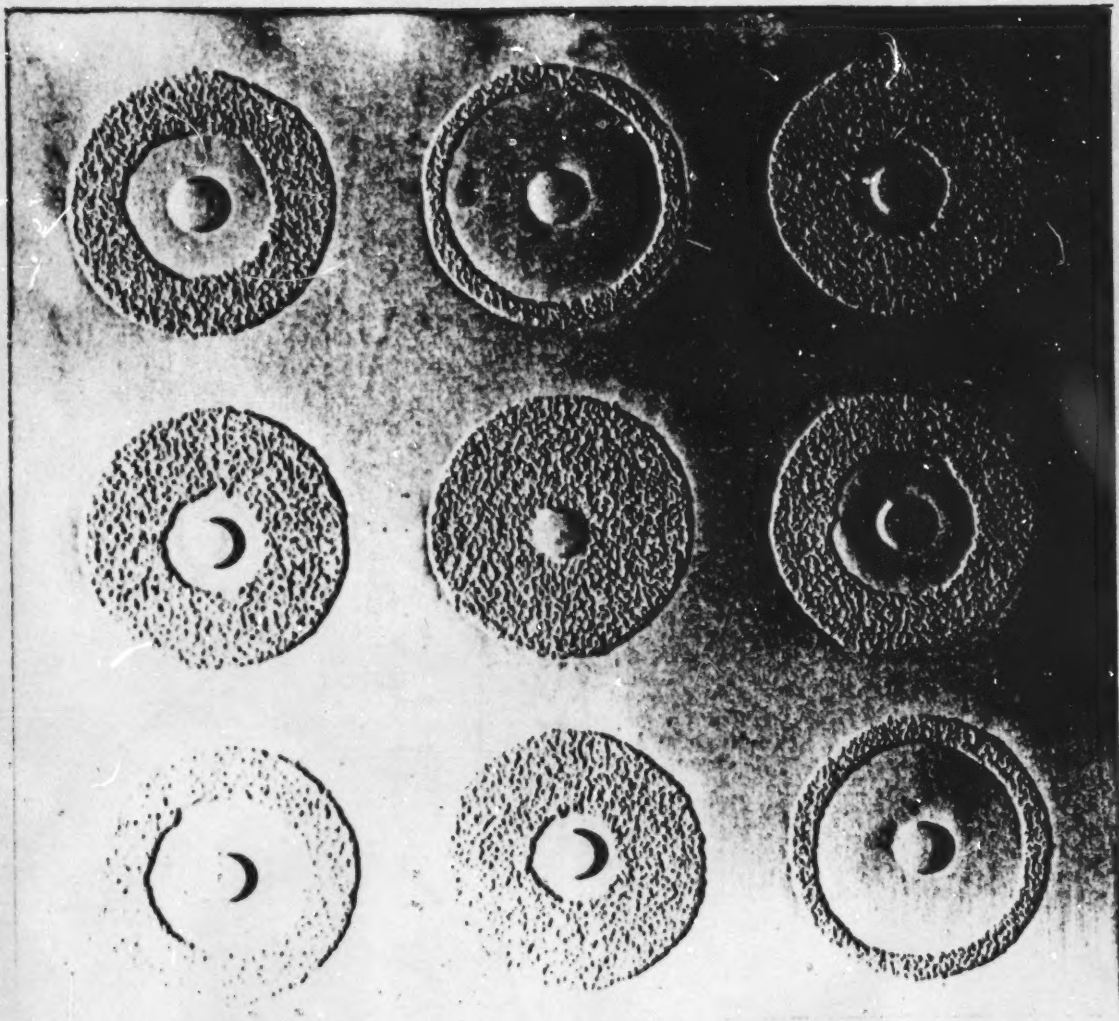


Figure 6-5. Bacteria Plate 2.

zones of inhibition around each disk the student compares the effects of the different household products on a specific kind of bacteria. The same symbols are used in this diagram as in the previous diagram (Figure 6-4).

Mapping Chromosomes

The techniques of providing data by a tactile diagram was also used in an activity which involved mapping chromosomes. In the regular lab activity the student examines a sample of ascospores with a microscope to observe the color patterns of the spores to ascertain if the segregation of the genes for color occurred at the first or second meiotic division. With these data the student calculates the chromosome map units for the two mutant genes.

The visually handicapped student uses a tactile diagram with twelve asci on it (Figure 6-6). The oval shapes with a dotted surface depict dark color spores and the oval shapes with a smooth surface depict light color spores. The student examines each ascus to determine its type: a crossover type (4:4 color arrangement) or a recombinant type (2:4:2 or 2:2:2:2 color arrangement). The student uses this information to calculate the map units as represented by this diagram.

The lab manual has a diagram to help explain how first and second division segregation patterns in asci occur. A tactile diagram is used by the visually handicapped student to obtain the same explanation (Figure 6-7). The top half of the diagram illustrates the color pattern when the genes for color are between the centromeres and point of cross-over. The bottom half illustrates the color pattern when the genes for color are not between the crossover and centromeres.

Mitotic Index

In the lab exercise on mitosis the students examine the tissue of an onion root meristem with a microscope to ascertain what fraction of the cells are undergoing mitosis, the mitotic index. A tactile

diagram is used with the visually handicapped student. The diagram depicts a small portion of tissue (Figure 6-8). The student observes how many of the cells given in the diagram are in some stage of mitosis and divides this number by the total number of cells observed. For the portion of tissue depicted by the diagram shown in Figure 6-8 the mitotic index is 0.66. As a follow-up question the student is asked to calculate the mitotic index from data collected by a class of students.

Blood Typing

In the lab the students determine their blood type. Since the visually handicapped students could not use the microscope they were unable to conduct the activity as designed. However, the students are given a tactile diagram that depicts the antigen and antibody reactions of the four blood types; and the reaction of blood cells to anti-Rh (Figure 6-9). This diagram shows either the presence of absence of clumping or agglutination, of blood cells for the

various reactions. A sighted person prepares the slide and then describes the absence or presence of clumping for each of the three antisera (Anti-A, Anti-B, and Anti-Rh) to the visually handicapped student. The student uses the tactile diagram to determine his/her blood type. The tactile diagram of bloodtyping also serves another function. The visually handicapped student can use it later to review what reactions occur under specific conditions.

Osmosis

In the lab activity on osmosis the students examine Elodea leaves that have been immersed in solutions of increasing concentration. Since this involves the use of the microscope, alternative activities were sought for the visually handicapped students.

An activity that simulated this process was considered. In this activity the student is given a set of tactile diagrams to depict the number of plasmolyzed for each given molarity and then constract a graph to

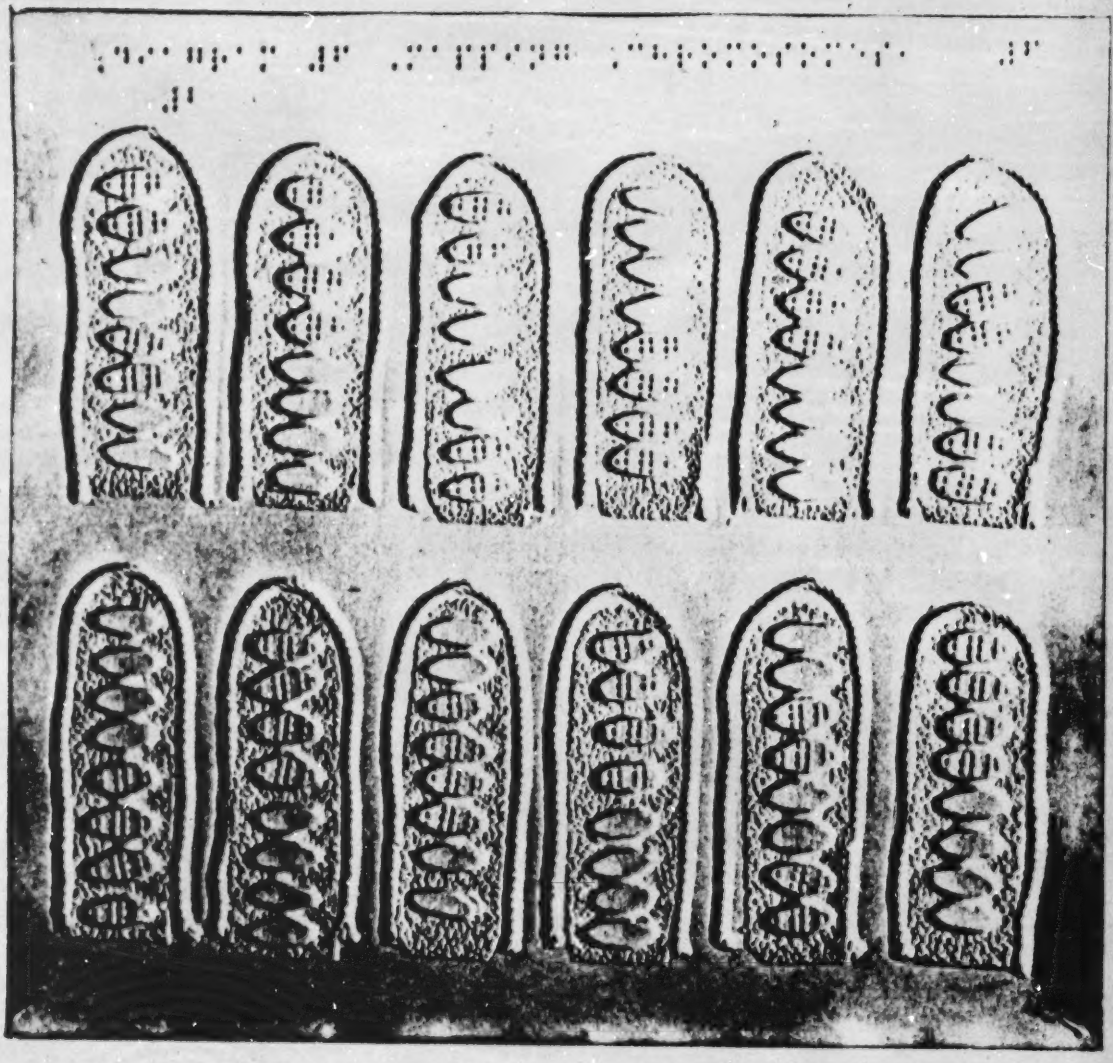


Figure 6-6. Mapping Chromosomes.

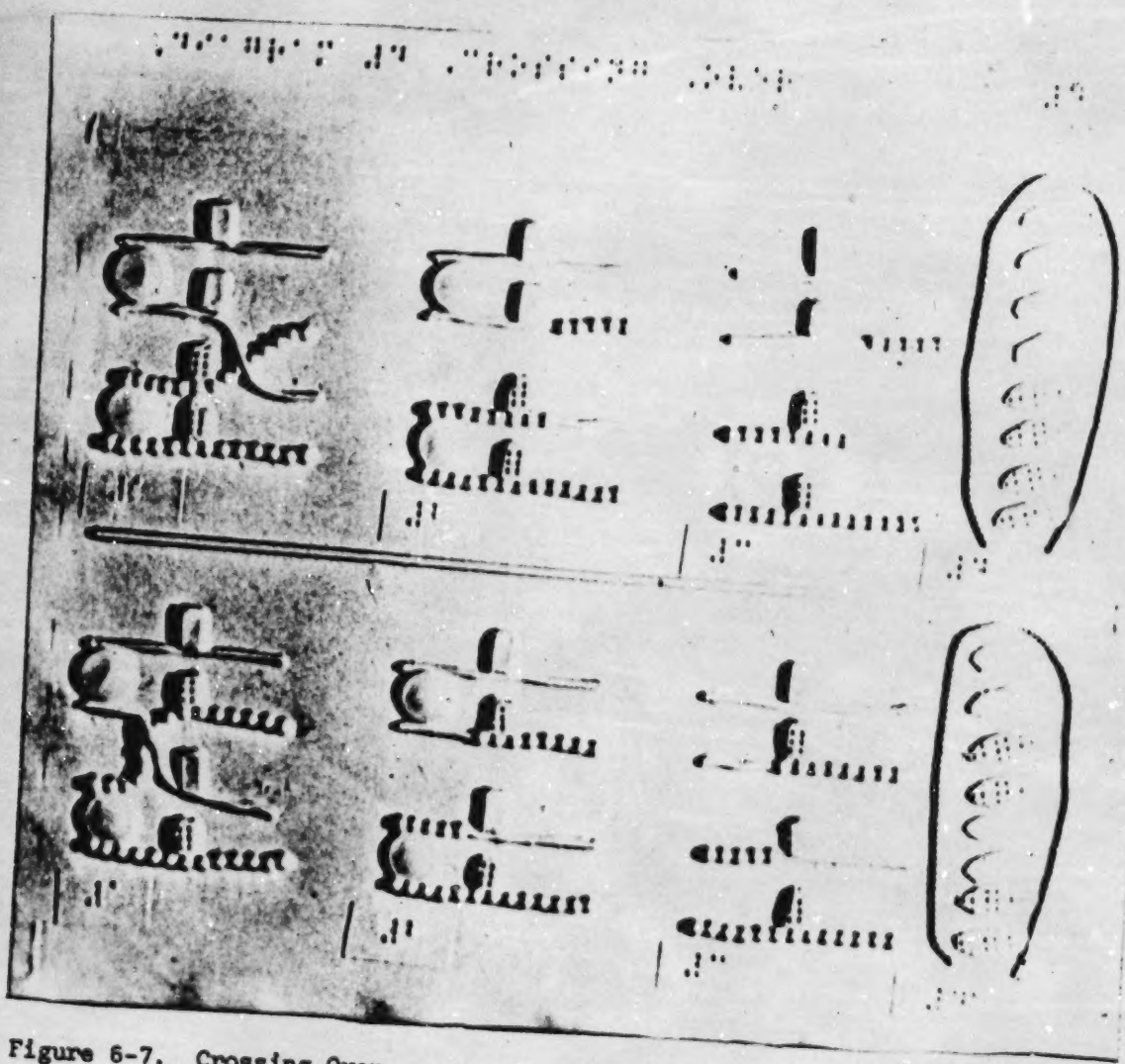


Figure 6-7. Crossing Over.

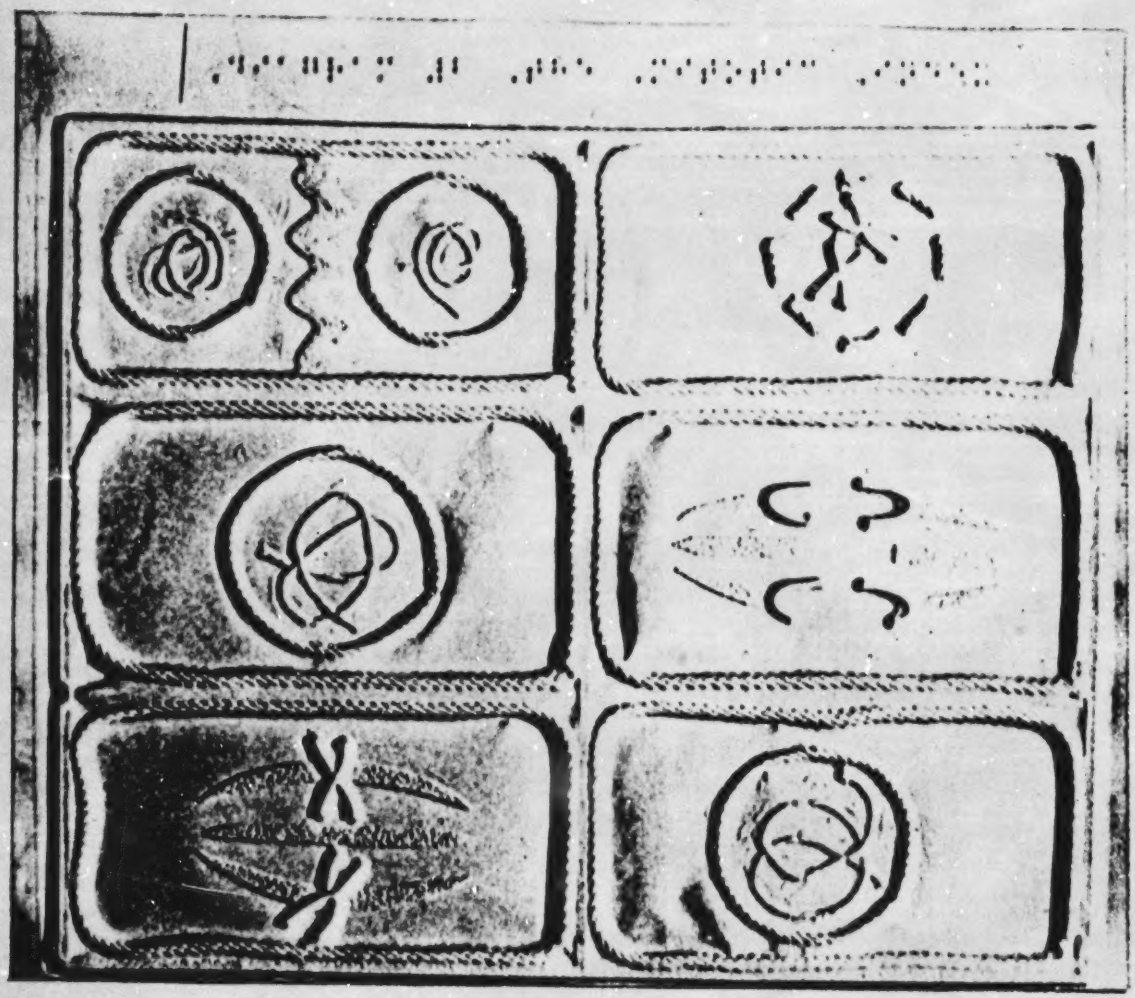


Figure 6-8. Mitotic Index.

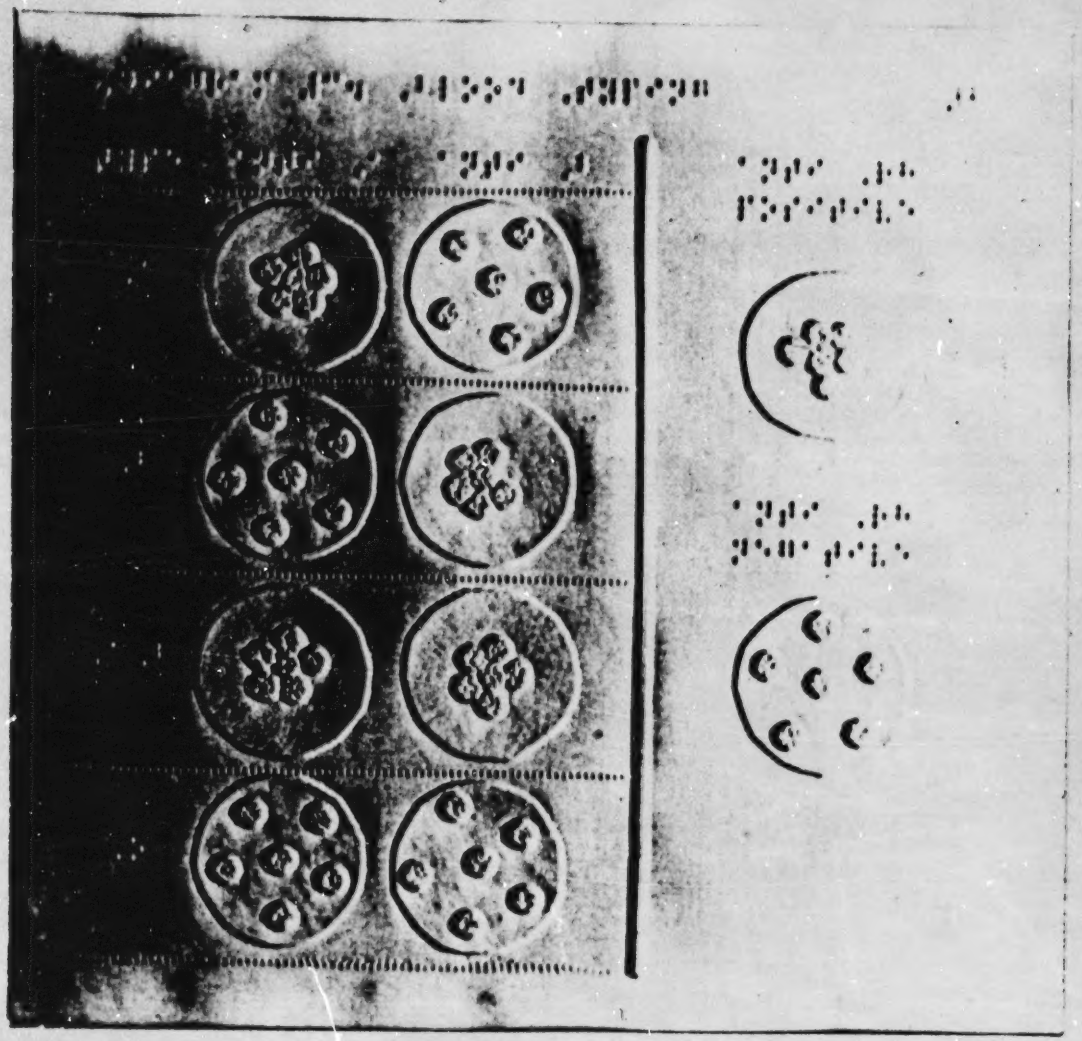


Figure 6-9. Blood Typing.

to estimate the iso-osmotic concentration for the solute. While the project recognized this as a potential activity, it was not tested. Rather the project used the following "hands-on" activity as an alternative strategy.

The student is asked to prepare a 1.0 molar sucrose solution. By having the student prepare one solution it introduces the student to the technique of making a molar solution without using an excessive amount of time by having him/her make several different solutions. A 0.4 molar sucrose solution and distilled water are made available by the instructor.

Next the student is given 3 sets of 4 potato cubes. The student measures the mass of a set and then places them in a container of distilled water; the mass of another set of potatoes is measured and placed in a 0.4 molar solution; and the third set is placed in a 1.0 molar solution after the mass is determined.

After the cubes have been submerged for one hour, each set of cubes is removed from the container,

blotted lightly and weighted again. The student calculates the percent increase or decrease for each set of potato cubes.

Using these data (along with data provided by the instructor for molar solutions of 0.2, 0.6 and 0.8) the student constructs a graph to estimate the concentration of sucrose that would be iso-osmotic to the cytoplasm of the potato. Note that some data are provided to avoid having the student spend an excess amount of time to do the activity.

Summary

When it was ascertained that the visually handicapped students were not able to do a laboratory exercise as designed, alternative activities and materials were examined. To the maximum degree possible, alternative activities and materials that would enable the visually handicapped student to be an independent learner were selected. In addition, the need for visually handicapped students to take a longer time to complete activities was also taken into account.

The chapter describes different kinds of alternative activities and materials that the project tried. In some cases the student handles and manipulates real objects; and in other cases the student makes observations by studying diagrams depicting real objects or reactions.

CHAPTER SEVEN -- Other Techniques

Some general techniques that the project identified for consideration when working with visually handicapped students are described in this chapter. These techniques are useable in a variety of ways during the duration of a course. The techniques are related to safety, making tactile diagrams that are not reproducible, solving mathematical problems, completing lab reports, tactile record sheets, and sensors.

Mathematical Problems

In several lab exercises the students are required to make mathematical computations. For example, they use the Hardy-Weinberg equation to calculate the gene frequencies for a trait in a population or determine the percent of weight change in potato cubes after being emerged in sucrose solutions. A talking calculator is a valuable aid for the students to make mathematical computations.

The talking calculator has an oral vocabulary of 24 words and can perform six functions: addition, subtraction, division, multiplication, percentages and square roots. If the instructor wants the students to show their work when doing mathematical problems, the students can use a tape recorder with the calculator to record their computations in order to "show" their work.

Lab Reports

The project identified several techniques that could be used for visually handicapped students to complete their lab reports. The particular technique used would depend on the abilities of the individual student and the type of lab reports that are to be completed. The techniques that were identified by the project are:

1. The student would write out the answers to the questions for the lab report, using a broad tip felt pen.

2. The student would tape or braille the answers to the questions for the lab report during the lab session. The student would then have 24 or 48 hours, depending on the length of the report, to type out the answers and submit them.

3. The student would tape the answers to the questions for the lab report during the lab session and submit the tape.

4. The student would give his/her answers to the questions for the lab report to the lab instructor or assistant orally before leaving the lab session.

5. The student would have a note-taker assigned to him/her for the lab session. The note-taker's task would be to write down the answers that the student wants to submit before leaving the lab session.

Tactile Record Sheets

The project also investigated the use of tactile record sheets on which the students could record their answers to questions for their lab reports. This technique allowed the student to submit tactile answers, have their answers evaluated, and have their answer sheets returned for feedback about their answers and for future reference. This technique was tested in two activities.

Genetics

For the lab report on genetics the student is asked to construct a tactile diagram to illustrate the results of inheritance through sex linkage. A tactile outline of the diagram is given to the student (Figure 7-1). This outline depicts the locations of the P1 and P2 rows; the F1 and F2 rows; and the Punnett squares for both the P1 and P2 crosses. The student receives three packets of tactile symbols: a packet of symbols to represent the normal X chromosome, a packet of symbols to represent the defective X chromosomes; and a packet of symbols to represent the Y chromosomes. The student uses a glue stick to attach the symbols to the diagram to illustrate the results of inheritance through sex linkage for a given situation. The student submits the diagram as part of his/her lab report. If the diagram contains mistakes, it is returned to the student, along with a tactile diagram giving the correct answers. Thus the student can compare his/her diagram with a correct diagram, and ascertain if he/she needs to seek additional help.

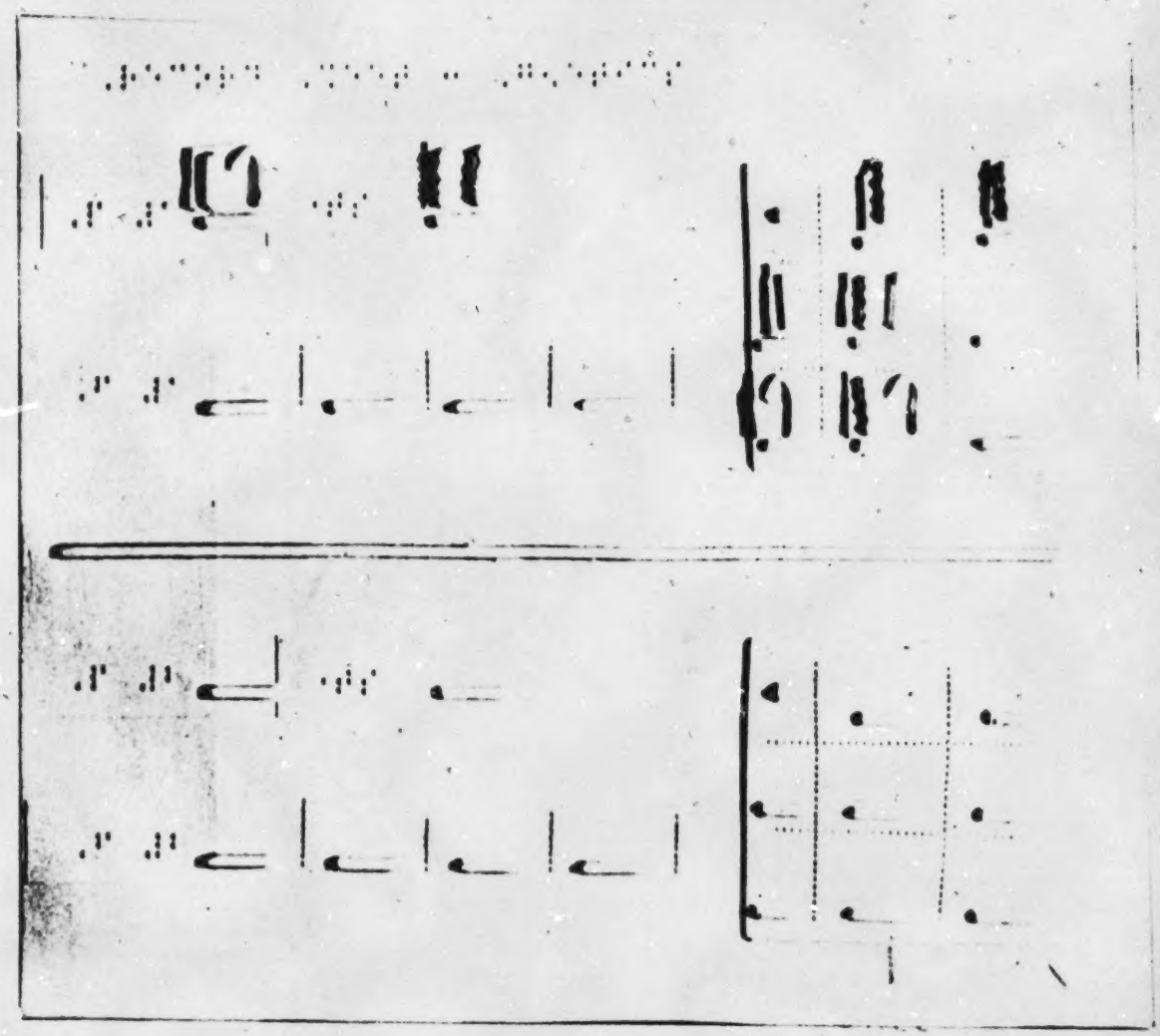


Figure 7-1. Genetics Record Sheet.

If the student's diagram is entirely correctly, it is also returned so the student will have it for reviewing purposes.

Human Blood

A tactile record sheet can also be used in the lab session that considered blood typing. The students are given a series of disputed paternity cases for which they must indicate what blood types would exonerate an accused man if the mother and child has certain blood types. For the tactile readers of braille this information is presented in braille. For each paternity case the four possible blood types are indicated. Following each blood type there is a raised circular surface. If the student wants to indicate that a particular type(s) of blood would exonerate the man, the student makes a braille dot in the raised circular surface immediately following the blood type, using a stylus that makes an inverted braille dot. This means the sheet does not have to be turned over and the braille dot formed by pushing a

regular stylus against the surface from the back side. When the student's answers are assessed, the letter X is brailled on the record sheet immediately following the raised circular surface if the student marked a wrong blood type; and the letter 1 is brailled after a circular shape to indicate that blood type was a correct response but the student did not identify it as a correct response. The record sheet is returned to the student so s/he receives written feedback regarding his/her responses, and so s/ne can use the record sheet for future review.

Safety Considerations

Two general factors regarding safety with which the project was concerned were: labeling and protection against accidental spillage. These factors are in addition to those mentioned in the previous chapters in regard to use of specific techniques.

It is imperative that objects be labeled in large print, braille, or by texture. Large print labels can be made by hand using a felt pen or by typewriter. A

large print embosser is available that can be used to make large print labels very quickly. Braille labels can be made on transparent adhesive tape with a slate and stylus or a braille writer. A braille embosser is available for making both magnetic and adhesive braille labels.

Whenever possible it is advisable to use distinctly colored and textured containers for specific purposes. For example, a bright red wash type bottle with a vertically ribbed surface can be used to indicate the contents of the container are flammable. If a container does not have a distinct shape or surface texture and there is a need to be able to readily identify it, a texture can be added to the outside of the container. Two bands of sandpaper around a glass container of acid will alert the student to this fact when the container is touched. For visually handicapped students who cannot read braille or large print this may be the only means for them to recognize that they have picked up a container of acid.

When students have a wet-lab the use of vinyl sleeve protectors and aprons should be considered as partial protection against accidental spillage.

Although there were no wet-labs that dictated the use of protective glasses or goggles the project was aware of the need to take extra cautions about eye protection. It may be necessary to have some visual handicapped students wear protective goggles when not normally considered essential for other students. In some cases, particularly for totally blind students, face shields should be considered as a means of protecting the face. With either limited or no eye sight, the students lack the normal reflex actions that other students have.

Sensors

The project tested the three sensors in Figure 7-2. These sensors respond to differences in light intensity and emit a sound that varies in pitch. The brighter the light, the higher the pitch will be. For the purposes of the project the sensor in the

center of Figure 7-2 was the most functional and versatile. This sensor, called an Audicator, was used to accomplish several tasks. Different accessories can be plugged into the Audicator so the device can be used for different purposes (Figure 7-3).

The light sensor on the cable was used with the Audicator to inspect the genetic corn (described in Chapter 6). This same accessory was attached to the Ohaus Cent-O-Gram balance so the students could use the balance to measure the mass of objects (described in Chapter 5). The liquid level indicator was used with a device to measure large volumes of liquid (described in Chapter 4). The small plug-in sensor is activated by inserting it into the socket of the Audicator, and functions continuously until it is pulled out. The clip leads can be attached to the Audicator to test electric circuits.

The Audicator is available with an earphone jack which will permit the use of the Audicator without disturbing other students. In addition, a special Audicator with a black-white detector is available.

The detector contains a light source and a sensor on the end of a cable. With this device it is possible to discriminate at close range between areas of high light reflectivity and low light reflectivity.

Tactile Diagrams -- Not Reproducible

In Chapter 4 the design and use of reproducible tactile diagrams is discussed. There are techniques that can be used to make tactile diagrams that are not going to be reproduced in multiple copies. These techniques vary in complexity, the time it takes to make a diagram, and the quality of diagram that is produced. The techniques investigated by the project are described below.

Sewell Embossing Apparatus

This apparatus consists of a clip board with a gum rubber surface and a modified ball point pen (Figure 7-4). The pen is slightly larger than a regular ball point pen and in which the ink has been replaced by a colorless lubricant.



Figure 7-2. Sensors.

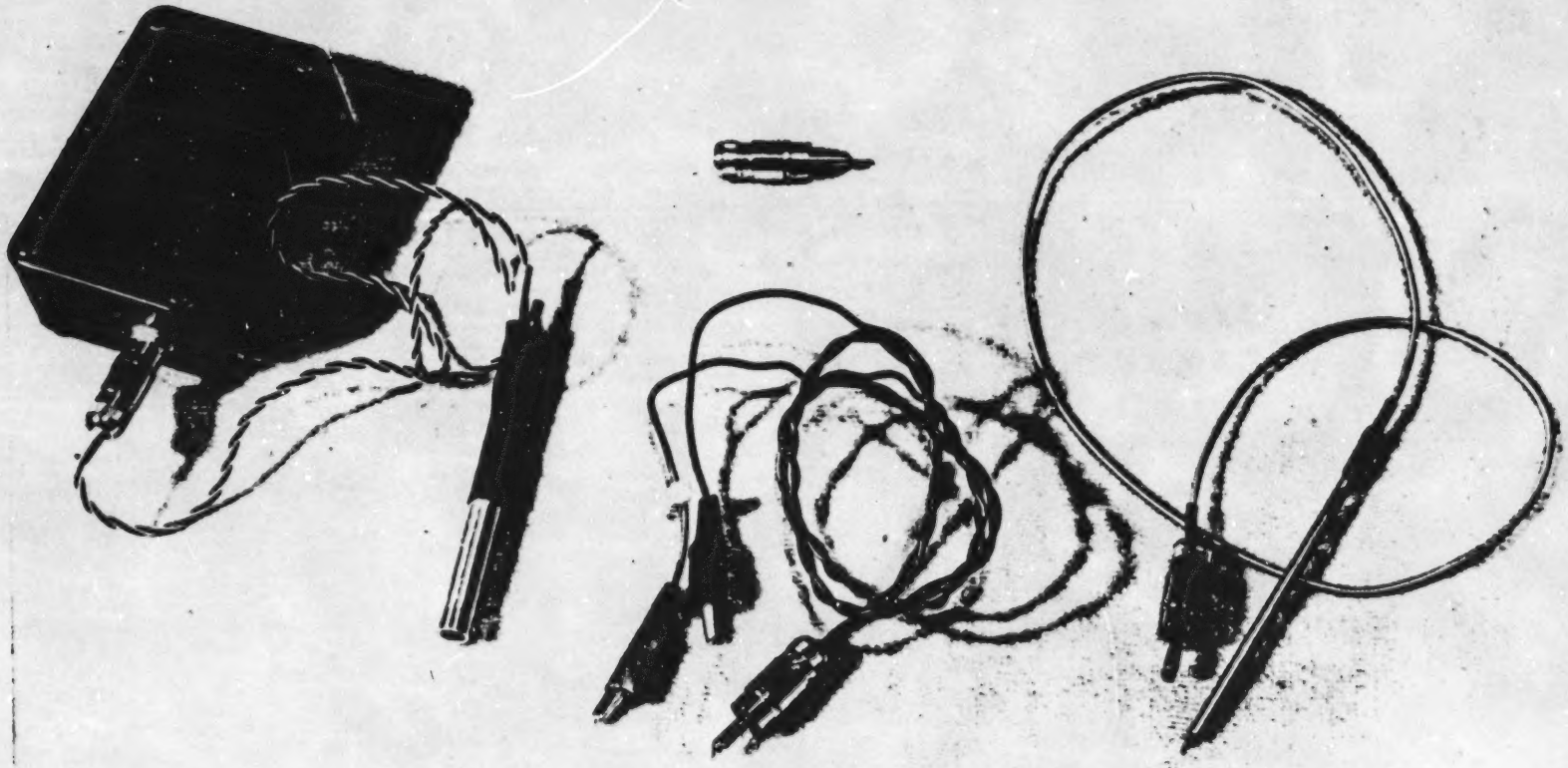


Figure 7-3. Audicator.

A sheet of plastic paper is placed on the clip board and the pen is used to draw a diagram on the plastic paper. The downward force exerted on the pen as it is moved causes raised lines to be formed on the top surface of the plastic paper.

The plastic film which comes with the kit is a Mylar type plastic film. The project tested several other plastic materials in terms of expense and quality. Overall, the project found that polyethylene plastic sheeting (4 mil thickness) that was cut into 8 X 11 sheets is an excellent substitute for plastic film provided with the kit.

This type of diagram is not durable. However, it is easy to make a diagram spontaneously when the need arises in a teaching situation. Care has to be exercised when using this type of diagram since they are not as readable since the lines are not consistent in form.

The amount of information that can be depicted in a single diagram is limited since an array of different textures and lines are not used by using only the

inkless pen. This problem can be solved partially by using a tracing wheel used for sewing purposes. By turning the sheet over and moving the tracing wheel over the plastic sheet a raised dotted line can be formed. Or a braille stylus can be used to make braille dots in the plastic sheet. These techniques make it possible to make lines that are tactually different and surface areas that will also feel differently. The disadvantage of using these techniques is the necessity to work on both sides of the plastic sheet. The pen is used on the top side while the tracing wheel and stylus are used on the bottom side.

Swail Dot Inverter

This device consists of a rubber pad and a specially designed stylus which permits upward embossing of braille dots (Figure 7-5). This means that a diagram consisting of lines composed of braille dots can be made from the top surface of a sheet of braille paper or plastic sheet. It is recommended that Brailon plastic sheets be used.

The diagrams produced by this technique are not durable. The diagrams are limited to lines of braille dots. While different lines can be depicted by altering the spacing between dots, or by altering the number of dots amassed in different areas, the amount of information that can be depicted effectively in one diagram is limited.

The project found that the specially designed stylus is useful for students to mark their answers on record sheets. The stylus allows braille dots to be made in the desired location without turning the sheet over. When a regular braille stylus is used it is necessary to turn the sheet over so the braille dot can be formed on the top surface by pushing in the stylus on the bottom surface.

Alternative Techniques

A kit to make tactile diagrams can be assembled with items found locally. Several different materials can be used for a drawing board. Regular screening wire and felt taped to a board have been used by some people. The project found a rubber pad (butyl rubber about 4mm thick) works best as a drawing board. For drawing tools the following devices are functional: ball point pen, steel probe with blunt end, tracing wheel, braille stylus, and pencil.

Various kinds of materials can be used for the drawing paper. The kind of material that is used depends on the amount of information that needs to be depicted, the degree of durability desired and the cost factor. Several materials that were tried are described below.

1. Polyetheylene sheeting can be cut into 8 1/2 by 11 inch sheets. One sheet with a thickness of 4 mils cost less than 2 cents.* A tracing wheel, blunt pencil point and braille stylus can be used to make 3 different types of raised lines. This material is the least expensive one used, but the diagram is not durable.

2. Aluminum foil sheets can be made with a double thickness of heavy duty foil. A 8 1/2 by 11 inch sheet costs about 5 cents. A

*Estimated costs as of March, 1980.

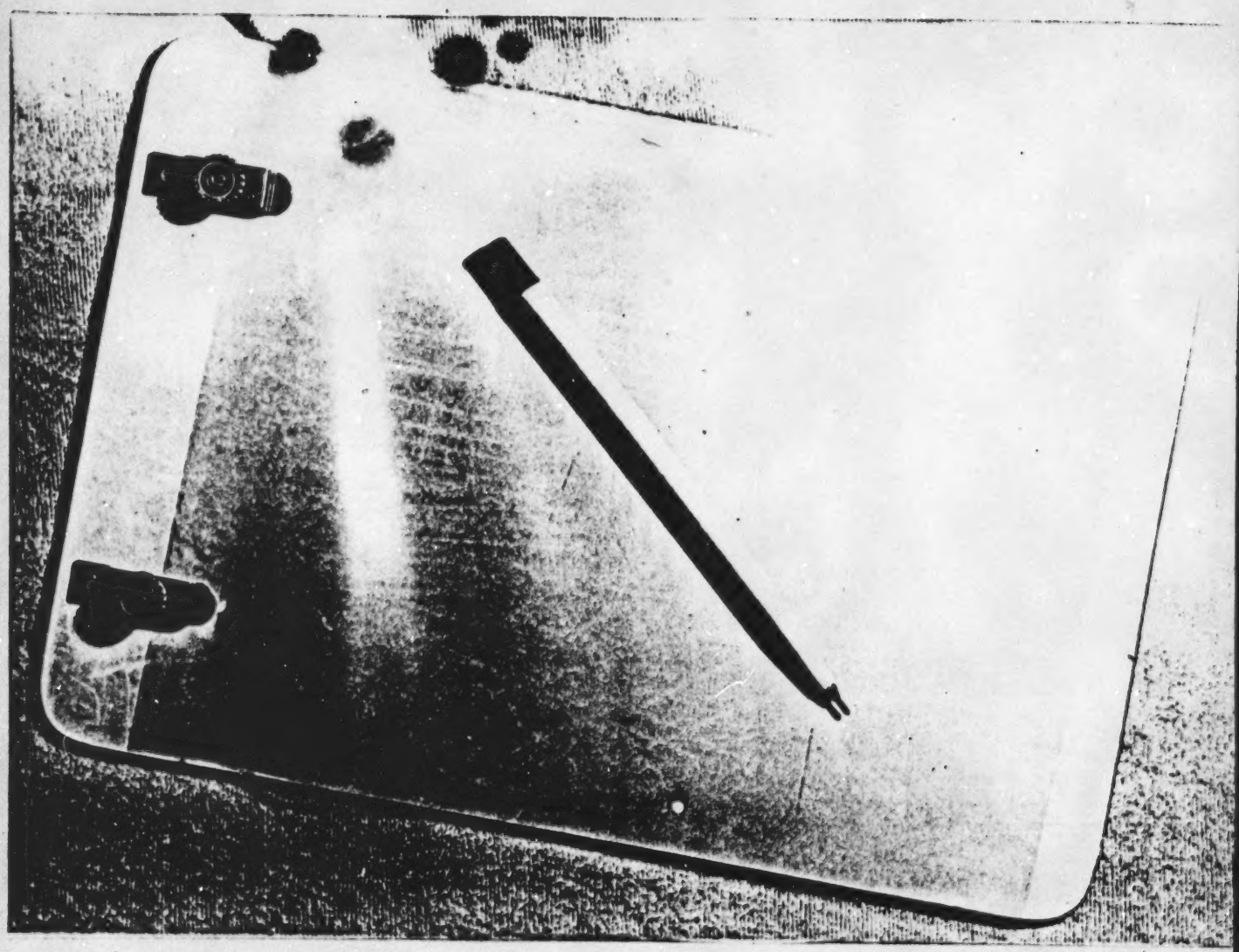


Figure 7-4. Sewell Board.

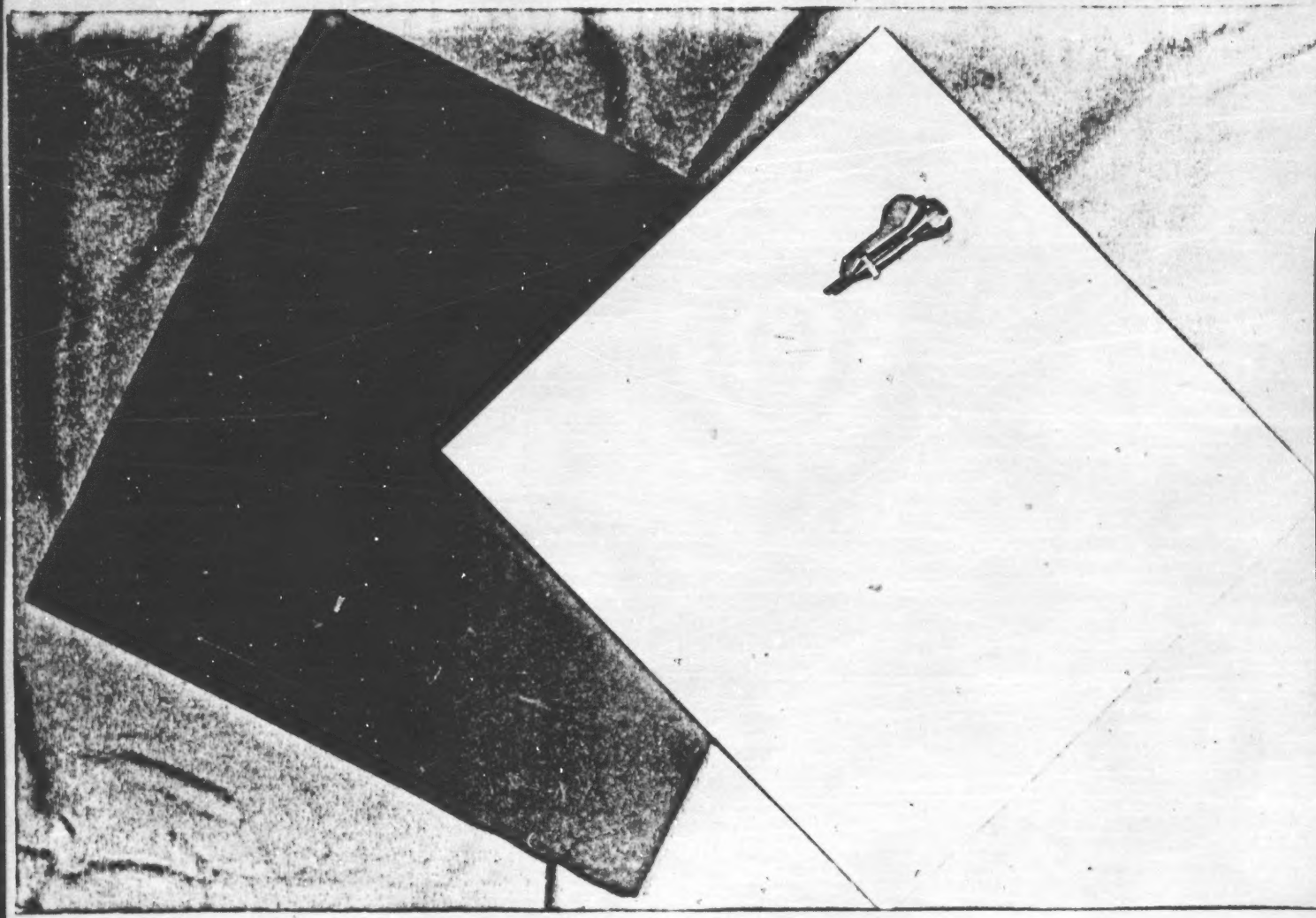


Figure 7-5. Swail Dot Invertor.

tracing wheel, blunt pencil point and braille stylus can be used to make 3 different kinds of raised lines. These lines are the least durable for the materials being described in this paper. While unwanted impressions can easily appear on the surface of the foil, it is easy to erase these marks.

3. Manilla sheets can be made by cutting a manilla filing folder apart. While a new folder costs about 10 cents, if old discarded folders are used this costs is greatly diminished. Two different kinds of raised lines may be made with a tracing wheel and braille stylus. A diagram on this paper has better durability than those materials previously identified.

4. Plastic report covers can be cut in half for drawing paper. The cost of each sheet is about 15 cents. The tracing wheel and braille stylus can be used to make two different kinds of raised lines. A diagram made on this plastic is the most durable of any of the materials described.

5. Mylar plastic sheeting can be cut into sheets at a cost of about 15 cents. Three different kinds of raised lines can be made with a tracing wheel, blunt pencil point and braille stylus. This type of diagram is not quite as durable as the diagram made on the plastic report cover, but it does allow three different kinds of raised lines to be used.

All of the above techniques use raised lines that are solid or composed of a row of dots. Thus, the complexity of the diagram is limited. To construct a

diagram that includes more information and is readable, other techniques should be considered. Probably the best technique is the cut and past method described below.

6. Cut and Paste -- For this technique the following materials are needed: Elmer's glue; scissors; manilla (or other sturdy) paper, and a box of odds and ends (buttons, fabric, twine, yarn, string, sandpaper, pipe cleaners, etc.). To construct a diagram the different materials are glued to the drawing paper. These materials serve as the symbols for the various components of the diagram. It is possible to construct this type of diagram without using Elmer's glue by using self-adhesive plastic sheets. First remove the protective shield to expose the sticky surface. Place the materials on the sticky surface. After all the materials have been stuck to the sheet brush the surface with talcum powder. This will eliminate the stickiness of the surface where materials are not placed. Figures 7-6 and 7-7 show diagrams made with this method.

While this type of diagram generally will take longer to construct it is possible to depict more information. The visually handicapped students also find this type of diagram more easy to read than the other types of diagrams in which only raised lines are used. They prefer to feel "real" textures.

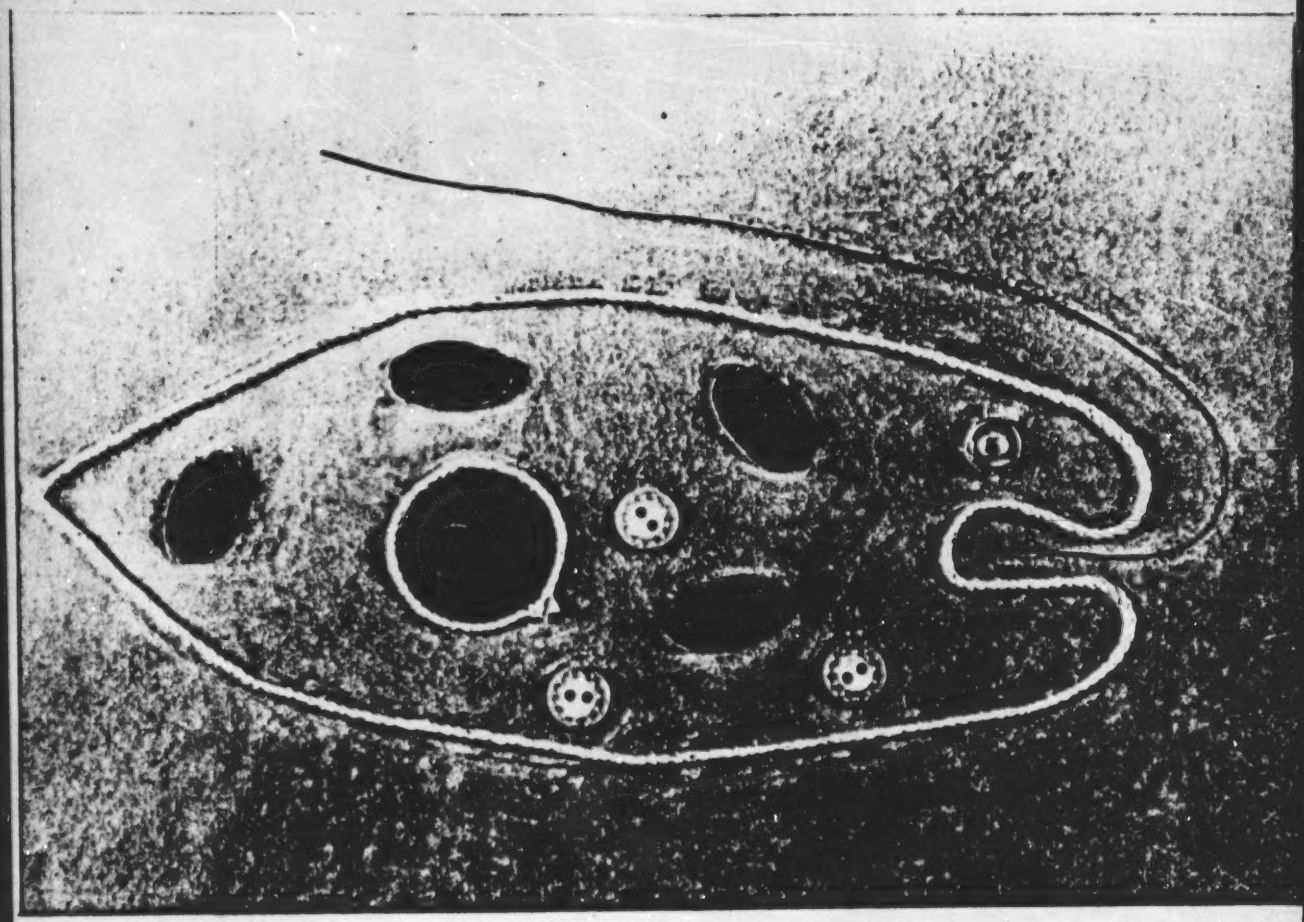


Figure 7-6. Euglena Cell.

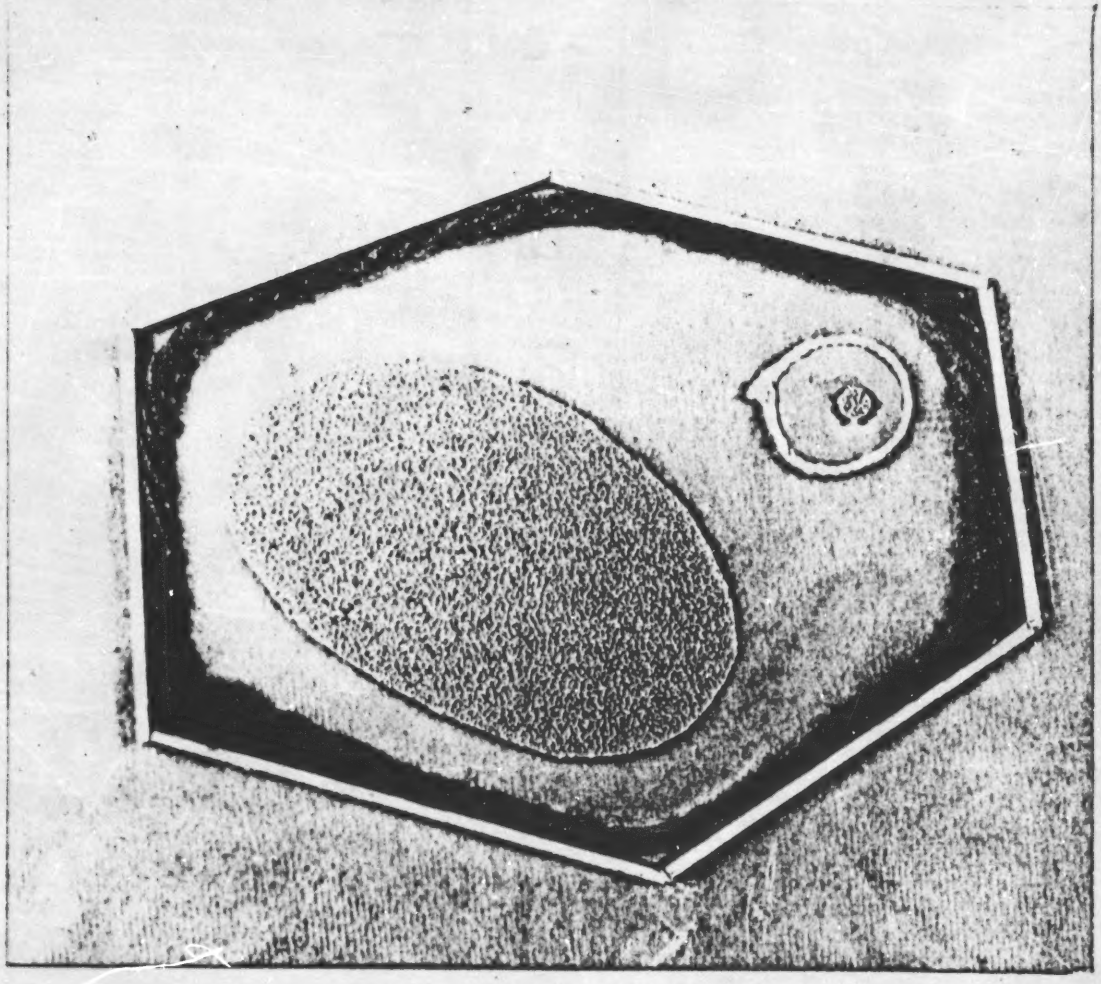


Figure 7-7. Onion Skin Cell.

A variety of techniques that can be used to make tactile diagrams for visually handicapped students have been identified. The factors that should be considered in determining which technique that is used are:

a. Complexity -- How much information needs to be depicted in one diagram?

b. Readability -- Is there adequate discrimination among the symbols used with the technique?

c. Durability -- Will the symbols last long enough for the diagram to be useable for the necessary period of time?

d. Cost -- How much will it cost to make a diagram with this technique?

e. Time -- When is the diagram needed? Is it needed right now to clarify an idea, or can it wait for a day or two?

f. Number -- How many copies of the same diagram are desirable?

g. Personal Preference -- What technique is the easiest for me to use?

Summary

There are a variety of general techniques which can be used to help make biology courses accessible

to visually handicapped students. The application of these techniques will depend on the conditions in which they are to be used. Since conditions can vary greatly from one situation to the next, it is impossible to write a manual in which techniques are prescribed. Rather the instructor should use the ideas in the manual as a springboard to create solutions to the specific problems they encounter.

CHAPTER 8 -- Conclusion

A resource manual of this sort should not have a concluding chapter. This manual represents only a part of the movement to generate knowledge that will ultimately enhance the opportunities for visually handicapped persons to acquire higher levels of scientific literacy and encourage some students to pursue science-related careers.

There will be a need to take the information contained in this manual and put it along side the information now being generated by other similar investigations. Once all this information is analyzed so as to provide an organized body of knowledge, we will be much closer to the goal of having all visually handicapped students fully integrated into science courses. At that time a concluding chapter will be appropriate.

APPENDIX A

Sources

American Foundation for the Blind, Inc.
115 West 16th Street
New York, NY 10011

Brailling materials; large print embosser; braille embosser; Sewell Drawing Kit; light sensor.

American Printing House for the Blind
P. O. Box 6085
Louisville, KY 40206

Brailling materials; light sensor; Swail Dot Inverter; rear viewing screen; talking calculator; ruler.

American Thermoform Corporation
8640 E. Slauson Avenue
Box 125
Pico Rivera, CA 90660

Thermoform Brailon Duplicator; Brailon paper; braillabels.

Bel-Art Products
Pequannock, NJ 07440

Dispensers; plastic lab ware.

Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215

Two X two slide transparencies; microscopic slides; viable seeds; chromosome simulation kit.

Fisher Scientific Company
711 Forbes Avenue
Pittsburgh, PA 15219

Dispensers; microscopic slides; microscope viewing screen; microprojector.

General Scientific
Limekiln Pike and Williams Avenue
Philadelphia, PA 19150

Safety lab supplies.

Howe Press of Perkins School for the Blind
Watertown, MA 02172

Brailling materials; tools for making raised diagrams.

Hubbard Scientific Company
P. O. Box 104
1946 Raymond Drive
Northbrook, IL 60062

Animal cell model, mitosis model.

Nalge Company
Division of Sybron Corporation
P. O. Box 365
Rochester, NY 14602

Plastic lab ware; dispensers.

National Teaching Aids, Inc.
120 Fulton Avenue
Garden City, NY 11040

Micro-Slide-Viewer; Genetics Made Easy Kit.

Science for the Blind, Inc.
Box 385
Wayne, PA 19087

Audicator; Aud-a-mometer (thermometer).

Visualtek
1610--26th Street
Santa Monica, CA 90404

Closed circuit television systems.